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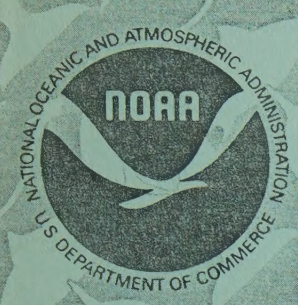

SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
P.O. BOX 271
LA JOLLA, CA 92038

MAY 1982

DIRECTOR'S REPORT
To The
THIRTY-THIRD TUNA CONFERENCE
On
TUNA AND TUNA-RELATED ACTIVITIES
At The
SOUTHWEST FISHERIES CENTER
LA JOLLA, CALIFORNIA
For The Period
MAY 1, 1981 TO APRIL 30, 1982

ADMINISTRATIVE REPORT LJ-82-07

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THIRTY-THIRD TUNA CONFERENCE

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TUNA AND TUNA-RELATED ACTIVITIES

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INTRODUCTION

With the exception of research on Atlantic billfishes and bluefin tuna which is carried out at the National Marine Fisheries Service (NMFS), Southeast Fisheries Center at Miami, Florida, all other studies on tuna in the federal government are conducted at the NMFS Southwest Fisheries Center's two laboratories in Honolulu, Hawaii, and La Jolla, California.

Tuna research at the Honolulu Laboratory is focused on studies of the sensory and physiological reactions of tunas to their environment, South Pacific albacore and other tuna populations of the central and western Pacific, and recreational fisheries research, principally the sportfishery for billfishes. At the La Jolla Laboratory, the staff of the Oceanic Fisheries Resources Division provides basic fishery analysis and management information on tunas and billfishes to international fisheries bodies and commissions, and conducts studies on the status of porpoise involved in the eastern tropical Pacific tuna purse seine fishery. The staff of the Coastal Fisheries Resources Division conducts biological research on North Pacific albacore which is directed toward an understanding of the fish/fishery/environment interactions.

Tuna research at the Southwest Fisheries Center during the past year was characterized by steady progress toward goals and objectives previously defined by the Center staff in 1979 and 1980: To deliver scientific information and advice to NMFS, the Department of State, U.S. Commissioners to international commissions, and U.S. delegates and negotiators participating in bilateral or international negotiations.

Among the notable developments in tuna research at the Southwest Fisheries Center was the increasingly close cooperation at the international level in research on North Pacific albacore. Center scientists joined their Japanese and Canadian peers at the Sixth North Pacific Albacore Workshop to exchange data, evaluate the condition of the resource, and present research results. In 1981, the Far Seas Fisheries Research Laboratory in Japan and the Southwest Fisheries Center extended an invitation to the Canadian Pacific Biological Laboratory in Nanaimo, British Columbia, to join the informal, laboratory-to-laboratory agreement which forms the basis of the Albacore Workshop series. This invitation was accepted and the Canadian scientists now participate and share in the research responsibilities associated with the albacore resource.

Another important area of research was the continuing effort by Center scientists to understand the albacore population and fishery dynamics. Major emphasis was on the development of a North Pacific albacore population model. The model, still under development, is designed to test hypotheses on the dynamics of the albacore population, including responses to changes in fishing effort and response to environmental factors. The ongoing expansion of the tuna data management system at Honolulu has included data used in the development of this model.

A significant achievement of the past year was the discovery by a research team of magnetic material in the skulls of yellowfin tuna, a clue to their ability to carry out ocean-wide migrations. The team has shown that tropical tunas are easily conditioned to earth-strength fields and that these fish possess magnetite (a highly magnetic iron oxide material) in their ethmoid sinuses in sufficient quantities to serve as the basis for a magnetic sense.

A major finding, and one with important implications for U.S. fishermen, came about as a result of the Center's cooperative study with the American Fishermen's Research Foundation. The results of the study show that the U.S. albacore fishery can be extended to operate during winter months, using longline fishing methods, in an area where the fleet has not traditionally fished. This potential for a mid-winter albacore fishery is an important alternative for individual U.S. fishermen, who formerly had only the choices of participating in other winter fisheries or remaining idle. It remains to be seen, however, if the overall catch will increase due to additional participation.

Other continuing activities at the Center include providing basic fishery analysis and management information on tunas in support of the U.S. commitment to the International Commission for the Conservation of Atlantic Tunas (ICCAT) and to ICCAT's Standing Committee on Research and Statistics (SCRS). Another important area of involvement was our participation for the third year in ICCAT's International Skipjack Year Program (ISYP), which is now focused on evaluating data collected in past years.

Studies also continued on the elucidation of population size and on the biology of dolphins involved in the tuna purse seine fishery of the eastern tropical Pacific, with new approaches tested to improve stock assessment analysis.

SWFC fishery biologists continued their effort to induce spawning skipjack tuna using the "stress-induced" method. Although the eggs hatched, the tuna larvae did not live beyond the 12th day.

The report which follows is not intended as a comprehensive presentation of the Center's studies on tuna and tuna-related fishes but rather as an informal account of major activities, accomplishments, and advances carried out in fulfillment of our mission as a center of tuna research in the federal government.

Izadore Barrett

Izadore Barrett, Director
NMFS Southwest Fisheries Center

May, 1982

IN SUPPORT OF EXISTING INTERNATIONAL AGREEMENTS

RESEARCH ON ATLANTIC TROPICAL TUNAS AT THE SOUTHWEST FISHERIES CENTER

During 1980-1981, research continued at the Southwest Fisheries Center on the stock assessment and fishery evaluation of Atlantic tropical tunas in support of fishery management needs and recommendations put forth by the International Commission for the Conservation of Atlantic Tunas (ICCAT) Standing Committee on Research and Statistics (SCRS). Species excluded from study by the SWFC are Atlantic bluefin tuna and billfish, which are subjects of research at the NMFS Southeast Fisheries Center in Miami, Florida.

U.S. fisheries were monitored and biological and fishery data collected as part of the research. Atlantic tuna imports were sampled (7,844 fish in 1980 and a preliminary count of 4,078 in 1981) for biological information in Puerto Rico. Results of the size-composition sampling from Puerto Rico in 1980 indicated that 72% by number of the yellowfin and 75% by number of the bigeye tuna imports sampled were under-sized (less than 55.0 cm fork length). The 1981 preliminary data indicate tentatively that 73% by number of the yellowfin and 74% by number of the bigeye tuna imports sampled were under-sized. Sampling for species composition in Puerto Rico during 1980 indicated that approximately 16% by weight of the imported mixed yellowfin/bigeye tuna tonnage sampled, consisted of bigeye tuna. An analysis comparing size compositions from imports sampled in Puerto Rico to size compositions of samples from landings in Tema, Ghana, was also conducted (see page 6 for paper by S. Herrick).

Atlantic tuna catch, effort, and biological data bases were updated and submitted to ICCAT. An analysis of biological data to derive a length-weight relationship for Atlantic bigeye tuna was undertaken in cooperation with scientists from Spain, Japan, and France (see page for paper by Parks et al). A histological gonad analysis of late summer-early winter collections of bigeye and yellowfin tuna from the northwest Atlantic and Gulf of Mexico was also conducted (see page 6 for paper by Goldberg and Herring-Dyal).

Research directed toward reducing the bias inherent in age-frequency estimates obtained from the deterministic von Bertalanffy growth relationship resulted in the introduction of a stochastic element into the relationship. This modification is expected to improve age-frequency estimates for Atlantic tuna stocks over those yielded by the traditional deterministic method (see page 6 for paper by Bartoo and Parker).

In support of ICCAT's International Skipjack Year Program (ISYP), U.S. port sampling activities in Puerto Rico have been expanded to collect gonad and stomach samples fom skipjack tuna caught in western Atlantic waters. The samples will be used for maturity/fecundity analyses and feeding behavior studies. In addition, length-frequency sampling coverage

of U.S. Atlantic skipjack tuna catches has been doubled for the remainder of the ISYP.

INTERNATIONAL COMMISSION FOR THE CONSERVATION OF ATLANTIC TUNAS

In support of the U.S. commitment to the 19-member International Commission for the Conservation of Atlantic Tunas (ICCAT) and its Standing Committee on Research and Statistics (SCRS), the staff of the Tuna and Billfish Resources Program at the La Jolla Laboratory provides basic fishery analysis and management information.

Atlantic Tuna Stocks Assessed at Meeting

In 1981, the ICCAT's SCRS meeting was held in Tenerife, Canary Islands, Spain, from November 3 to 11. The Center was represented at this meeting by Director Dr. Izadore Barrett, fishery biologists Dr. Norm Bartoo and Dr. Gary Sakagawa, and industry economist Dr. Samuel Herrick. Prior to the meeting, SCRS scientists prepared status of stock reports on Atlantic tuna and billfish stocks to assist the Commission in identifying needed conservation measures.

The Committee's assessment of the condition of yellowfin tuna stocks stated that on an Atlantic-wide basis, yellowfin tuna appear to be heavily exploited, with current catches approaching the upper estimate of maximum sustainable yield (MSY). While the Committee had no specific recommendation for additional management of yellowfin tuna at this time, it did recommend the continuation of investigations of alternative management schemes designed to enhance yellowfin tuna yields; these were begun in 1980 and were developed further in 1981.

The SCRS appaisal of bigeye tuna stocks indicates that on an Atlantic-wide basis, bigeye tuna are currently being exploited within the range of estimated MSY's. Considered separately, the fishery for bigeye tuna in the northern Atlantic is currently operating at a level below the estimated MSY for a distinct northern stock, while the fishery in the south is operating at a level close to the estimated MSY for a distinct southern stock. The Committee offered no new management recommendations for bigeye tuna at this time, but recommended that alternatives to the current minimum-size regulation for bigeye tuna continue to be investigated.

The Committee's assessment of skipjack tuna resources remains relatively unchanged from that of last year. Skipjack tuna in the eastern Atlantic are currently exploited at a higher level than in the western Atlantic. Although the true potential yield from the resource is still unknown, available information suggests that it is greater than the catch levels currently realized. There were no management measures recommended for skipjack tuna at this time. However, the Committee noted that because

skipjack tuna are frequently caught together with yellowfin and bigeye tunas, management aimed at these latter species will likely impact skipjack tuna catches.

The SCRS appraisal of albacore tuna stocks indicated that the northern stock is currently being exploited below its estimated MSY while the southern stock appears to be fished at a level near its MSY. There were no management recommendations made for albacore tuna at this time.

The SCRS assessment of the bluefin tuna resource suggests that while bluefin tuna in the eastern Atlantic are not currently threatened with over-exploitation given the current pattern of the fishery, fishing has reduced the resource in the western Atlantic to dangerously low levels. Based upon this assessment, the Committee recommended that current minimum size and fishing mortality regulations be maintained in the eastern Atlantic, and that catches of adult and juvenile bluefin tuna in the western Atlantic be reduced to as near zero as feasible in 1982. On the other hand, if bluefin tuna are to be managed on an Atlantic-wide basis, the Committee recommended that 1982 catches of adult fish be held to as near 9,500 mt as feasible, and that catches of juvenile fish be reduced to as near zero as feasible. This recommendation was based upon evidence showing low levels of abundance for both juvenile and adult fish.

While the exact status of Atlantic billfish (blue marlin, white marlin, sailfish, and swordfish) resources remain unknown, the Committee expressed concern over the low catch-per-unit-effort (CPUE) levels for both blue and white marlins in recent years, and the impact of increased levels of effort on these resources. The Committee noted that significant progress has been made in improving and updating billfish data bases; however, there is still insufficient information to make firm evaluations on the condition of the resources and the need for management at this time.

Reports were also prepared on the multispecies aspects of fisheries for both temperate and tropical tuna-like species. The Committee stressed the need to develop a plan that addresses ecological interaction issues and to establish an analytical framework for multispecies fishery assessment and management investigations.

The ICCAT Commissioners met from November 11 to 17, 1981, to consider the SCRS findings and to deal with housekeeping matters. Based on the SCRS Report which showed a decrease in the abundance of the Atlantic bluefin stock, the Commission recommended that the capture of bluefin tuna be prohibited for a period of two years in the western Atlantic Ocean and that directed and incidental catches be limited to an annual level of 800 mt to enable ongoing scientific studies to be continued.

SWFC Scientists Submit Tuna Papers to SCRS Meeting

The following papers were among those prepared by the SWFC's Tuna and Billfish Resources Program for presentation at the 1981 SCRS meeting:

Dr. Samuel Herrick authored a paper entitled "Size and species composition of Atlantic tunas from imports landed in Puerto Rico during 1980." This paper described results of length-frequency and species composition sampling of foreign-caught, imported Atlantic tunas transshipped to Puerto Rico during 1980. The Puerto Rican transshipment size-composition sampling results were compared to the results of landings sampled in Tema, Ghana, where the transshipments originated, using goodness-of-fit tests. Estimated length-frequencies obtained in Puerto Rico by sampling yellowfin and bigeye tuna transshipments of the Tema-based baitboat fleet were tested against expected length frequencies, based upon corresponding landings sampling conducted in Tema. The tests indicated that in the majority of cases, statistically significant differences exist between the results of the Puerto Rican and Tema sampling programs.

Co-authored by Dr. Norm Bartoo, SWFC, and Keith Parker of Creative Ideas, San Diego, a paper entitled "Stochastic age-frequency using the von Bertalanffy growth equation" detailed a technique whereby the bias inherent in the traditional method of estimating age-frequency from length-frequency using the deterministic von Bertalanffy growth equation is removed by incorporating a stochastic element in the von Bertalanffy relationship. The stochastic element is based on estimated probabilities of lengths by intervals at age; the probabilities are estimated from variances in lengths-at-age. Based on age-length samples from the Pacific bonito fishery, the stochastic method gives improved age-frequency estimates over those obtained by the deterministic method.

A paper, "Histological gonad analyses of late summer-early winter collections of bigeye tuna, Thunnus obesus, and yellowfin tuna, Thunnus albacares, from the Northwest Atlantic and the Gulf of Mexico," by Dr. Stephen Goldberg, Whittier College, and Hillary Herring-Dyal of the Southwest Fisheries Center, was submitted to SCRS for the 1981 meeting. In this paper, the authors acknowledge the dearth of information available on the reproduction of yellowfin and bigeye tuna in the Gulf of Mexico and adjacent Northwest Atlantic Ocean, and cite previous reproductive studies on samples from the Pacific Ocean which provide some information on the spawning of these species. In order to gain an understanding of the reproductive potential of yellowfin and bigeye, the authors carried out a histological analysis of the gonads. They conclude, based on their data, that the populations under study undergo a brief spring spawning period similar to that of northern fishes which have a restricted spawning season. They state, however, that in order to test their hypothesis of a postulated spring spawning period, it will be necessary to obtain additional female gonads for the period March through June for a more complete picture of the reproductive biology of yellowfin and bigeye tunas.

The fourth paper submitted to the SCRS meeting was entitled "Length-weight relations for bigeye tuna (Thunnus obesus) captured in the eastern Atlantic Ocean," by W. Parks, X. Bard, S. Kume, and A. Santos. The authors estimated parameters for a length-weight relation for bigeye tuna captured in the Atlantic Ocean between 30°N and 15°S latitudes and between 30°W longitude and the coast of Africa. Data were stratified by gear (surface and longline), area of season of capture, and by sex. The time period studied was 1957 to 1979, with material from 1971 to 1974 comprising 75% of the total. Analyses of covariance were used to test for length-weight relations due to area, gear, season, and sex. The results are tentative due to lack of data for many strata.

INTERNATIONAL SKIPJACK YEAR PROGRAM (ISYP)

The year 1981 marked the third year of SWFC involvement in the Atlantic-wide skipjack tuna research program now known as the International Skipjack Year Program (ISYP). Almost four years in the planning, the program is sponsored by ICCAT. The rationale for the program is that while scientists believe skipjack tuna to be the most abundant of the commercial species of tuna in the Atlantic, this species has only recently been exploited on a large scale. Since 1961, however, catches have increased rapidly, with a peak of 118,000 metric tons in 1977. The projected catch for 1981 was about 140,000 mt.

It appears from the above that there is potential for expanding production of Atlantic skipjack tuna. At present, however, insufficient information exists to plan this expansion in an orderly and rational manner to avoid damaging the skipjack stocks through overexploitation by an overdeveloped fishery.

The ISYP program was developed by ICCAT to help fill in these gaps in information. ICCAT coordinated the collective inputs of the 19 member countries who supply the vessels, gear, and research expertise required to implement the program. A planning phase was carried out during 1979, a limited execution phase started in 1980, and research conducted in 1981. The final year of the program, 1982, will focus on analysis of the data collected.

Center Scientists Aids Brazilian Tuna Tagging Program in Support of ISYP

In October 1981, Dr. Ronald Rinaldo, Fishery Biologist at the Southwest Fisheries Center, returned after a one-month trip to Brazil where he trained scientists from the Superintendencia do Desenvolvimento de Pesca (SUDEPE) and Empresa de Pesquisa Agropecuaria (PESAGRO-RIO) in techniques for tagging tuna. The trip was made on behalf of the government of Brazil and ICCAT in support of the ISYP. Rinaldo participated in two training cruises aboard the PESAGRO-RIO research

vessel, Malacostraca, preceding the Brazilian tagging effort scheduled to start in late January 1982 and continue through April. Fourteen Brazilian scientists were trained in tagging and biological sampling procedures contained in the ISYP field manuals.

The Brazilian tuna fishery is a pole-and-line fishery that primarily catches skipjack tuna. Approximately 80 vessels with crews of 18-25 men are currently fishing within 150 miles of the States of Rio de Janeiro and Sao Paulo.

Skipjack Sampled and Tagged for Fishery Studies

As part of the U.S. contribution to ISYP, the staff of the Tuna/Billfish Resources Program of the SWFC conducted a skipjack sampling and tagging cruise aboard the baitboat, Rhonda Sue, in the Caribbean and western Atlantic between the Dominican Republic and the coast of Surinam, from February 4 to April 18, 1980. One hundred forty-three schools of tuna/tuna-like fish were sighted during 54 days on the fishing grounds. A total of 1,612 fish was tagged with dart tags. Skipjack tuna accounted for 1,412 of the tagged fish: 1,074 were single-tagged, 121 were double-tagged, and 217 were tagged and injected with tetracycline. The tetracycline injection will place an event mark on the hard parts of the fish which can be examined for growth studies when the fish is recaptured.

Otolith samples for ageing studies were taken from skipjack captured during the Rhonda Sue cruise. Twenty skipjack otoliths were collected and retained for future analysis. To date, only one tetracycline-marked fish has been recovered and returned to the SWFC's La Jolla Laboratory. Alex Wild, Biologist with the Inter-American Tropical Tuna Commission, is studying this specimen to obtain a reading on age/growth. About 50 uncleaned skipjack otoliths collected in 1977-1979 are available at the La Jolla Laboratory from fish transshipped to Puerto Rico from the eastern Atlantic and will be supplied to parties interested in ageing analyses.

Five plankton tows were made during the Rhonda Sue cruise and samples from these tows have been submitted to the NMFS Southeast Fisheries Center in Miami, Florida, for analysis. Approximately 140 XBT readings and 40 weather observations were also taken on the cruise to supplement existing sea surface temperature observations by U.S. purse seiners fishing in the Atlantic. These data are being evaluated in order to relate catch by species and set type to sea surface temperature.

U.S. scientists have already analyzed historical sea surface temperature data and catch effort data to delimit the distribution of skipjack tuna in the tropical Atlantic Ocean. A previous oceanographic study of Atlantic skipjack habitat used historical dissolved oxygen and vertical thermal structure data to hypothesize areas of skipjack vulnerability to surface gear in the western Atlantic Ocean.

A data base resulting from the skipjack tagging cruise aboard the Rhonda Sue has been established at the SWFC consisting of 1) raw data from

tagging sheets, and 2) length frequencies for tagged fish by month and 1°-latitude x longitude squares. In addition, International Skipjack Year tag recovery stations have been established in La Jolla and Puerto Rico to collect tag recovery and related information on recaptured, tagged tuna. These fish are retrieved by fishermen and cannery workers, as well as scientific technicians working in ports and aboard vessels. As of this writing more than 300 ISYP tags have been recovered at the U.S. stations; of these 7 were from fish tagged during the U.S. tagging cruise.

Port Sampling of Skipjack Continues

The U.S. continues to collect catch/effort and skipjack length-frequency data from U.S. vessels fishing in the Atlantic. Catch/effort coverage is approximately 100% for the U.S. vessels fishing in the Atlantic. Although skipjack length frequencies are adequately sampled at present, attempts are being made to provide increased sampling during the remainder of the International Skipjack Year Program. The U.S. plans to maintain this level of coverage while expanding the length-frequency sampling program to Brazilian baitboat fleet transshipments. U.S. port sampling activities at Puerto Rico have been expanded to collect gonad and stomach samples from skipjack tuna caught in western Atlantic waters. These samples are shipped to the SWFC in La Jolla for analyses of maturity/fecundity and studies of feeding behavior. Fishery biologist Dr. David Au of the SWFC is analyzing the gonad samples in order to determine: the location of skipjack spawning areas in the western equatorial Atlantic (W of 30°W longitude, 30°N - 30°S latitudes); time by month of spawning activity; size at first maturity; fecundity by size, area, and time; and sex ratios. The sampling design of this maturity-fecundity study requires that 50 female ovaries be collected per month over a 12-month period. Samples will be stratified according to fish size with each 50-fish sample evenly distributed over five 10-cm size intervals ranging from 40 to 81+ cm.

Stomach samples are currently being analyzed by SWFC scientists to determine the composition of stomach contents and to correlate any variations in food items with differences in the stage of sexual maturity. The ISYP plan points out that skipjack tuna may themselves be a major predator of their young and this analysis will examine that possibility for fishing areas of the western Atlantic Ocean.

Procedure Manuals Written for Skipjack Studies

Mathematician Atilio Coan and fishery biologist Dr. Ronald Rinaldo of the SWFC, with ICCAT staff member Dr. Philip Symons, designed and prepared manuals on port sampling, shipboard sampling, and laboratory manuals for ICCAT's International Skipjack Year Program (ISYP) which have greatly expedited ISYP data collection and processing. (Additional details about the ISYP are given on page 7.)

OVERVIEW OF UNITED STATES FISHERIES ON TUNA AND TUNA-LIKE FISHES OF THE ATLANTIC OCEAN IN 1980-1981

In 1980, U.S. commercial catches of Atlantic tunas and tuna-like species were approximately 20,000 metric tons (mt), an increase of approximately 14% over 1979. Catches of skipjack tuna increased by 16% while catches of bluefin, yellowfin, and bigeye tuna decreased by 34%, 33%, and 5%, respectively. Catches of swordfish increased 4%.

The U.S. fishery for tropical tunas operated under a minimum size regulation of 3.2 kg for yellowfin tuna, with a 3% incidental catch allowance by weight per boat landing, during all of 1980, and under the same minimum size regulation for bigeye tuna after it was implemented in the fall of 1980. The U.S. fishery for bluefin tuna operated under size, catch, and seasonal limitations.

Most of the Atlantic tropical tuna fishing activity by U.S. vessels during 1980 occurred in the eastern Atlantic. Eight purse seiners fished in eastern Atlantic waters, one more than in 1979. These vessels spent approximately 571 days fishing and caught 1,614 mt of yellowfin tuna, 2,608 mt of skipjack tuna, and 143 mt of bigeye tuna.

Catch rates during 1980 in the eastern Atlantic were 2.2 mt of yellowfin tuna and 3.9 mt of skipjack tuna per day's fishing, a 43% decrease and a 77% increase, respectively, compared with 1979.

In 1980, the catch of under-sized yellowfin tuna by the U.S. fleet was approximately 81% (by number) of the fleet's total yellowfin catch. The catch of bigeye tuna below 3.2 kg during all of 1980 was approximately 5% (by number) of the fleet's total bigeye catch.

In 1981, eight U.S. seiners participated in the Atlantic tropical tuna fishery. The 1981 preliminary total catch of Atlantic tropical tunas by U.S. vessels was 5,135 mt, with 1,757 mt of yellowfin tuna, 3,250 mt of skipjack tuna, and 128 mt of bigeye tuna. This is an estimated 7% decrease from the 1980 total catch, with a 15% decrease in the catches of yellowfin, a 2% increase in skipjack, and a 36% decrease in bigeye tuna catches.

IN SUPPORT OF POSSIBLE FUTURE INTERNATIONAL AGREEMENTS

NORTH PACIFIC ALBACORE

Sixth North Pacific Albacore Workshop

In keeping with the informal agreement reached in 1974 between the Southwest Fisheries Center (SWFC) and the Far Seas Fisheries Research Laboratory (FSFRL) of Japan for a joint program of research on the North Pacific albacore resources, the Sixth North Pacific Albacore Workshop was held from September 1 to 4, 1981, at the FSFRL in Shimizu, Japan. Representing the Southwest Fisheries Center at the Workshop were Drs. N. Bartoo and M. Laurs. As a preamble to the workshop, the participants noted the recent high utilization of the North Pacific albacore stocks and urged continued and intensive research efforts to obtain a better understanding of the biology and dynamics of the resource.

A summary of papers presented to the Albacore Workshop by U.S. researchers follows:

Dr. Laurs and Mr. R. Nishimoto, SWFC, described results of further studies ("Evaluation of the otolith daily ring method for age determination in North Pacific albacore") to test the assumption that increments of growth are deposited daily on the otoliths of albacore. Latest information confirms earlier indications that in tetracycline-injected tagged specimens, the relationship between otolith ring increments and days at liberty is close to 1:1. This opens the way to determining with considerable accuracy the length of albacore at first birthday. Furthermore, comparison of ages determined by otolith ring counts may help to resolve uncertainties in the ageing of albacore from finray cross-sections. (Additional details on the otolith study are given on page 16.)

In recent years an increasing amount of evidence indicates that the North Pacific albacore population is complex and probably consists of more than a single stock. Results from tagging studies, investigation of growth rates, and examination of size composition of fish caught in the North American surface fishery suggest that 1) there are at least two substocks of fish that comprise the North Pacific albacore population, and 2) these substocks have different migration patterns.

Dr. Laurs described the results of albacore growth rate studies that he and Dr. J. Wetherall have published. These studies, based on tag returns, show that fish from the proposed "northern" substock of albacore have a significantly slower growth rate than do fish from the proposed "southern" substock. This is supported by evidence that there are modal differences in the size composition of albacore caught north and south of about 40° N latitude in the North American surface fishery ("The North American fishery for albacore (Thunnus alalunga) in the North Pacific" by E. Weber and N. Bartoo, and "Review of the 1980 U.S. North Pacific albacore fishery" by R. M. Laurs and N. Bartoo).

To investigate further the population structure of the North Pacific albacore, an electrophoretic investigation of protein variability was conducted by J. Graves and R. M. Laurs ("An electrophoretic investigation of protein variability in the North Pacific albacore"). Forty-six loci were surveyed; four of these demonstrated allelic variation, with three being weakly polymorphic and one being highly polymorphic. These four loci can be used as genetic markers for further studies of population differentiation in the albacore because the polymorphisms appear to be stable. As all four loci are present in eye tissue, sampling of additional fish should be relatively simplified. On the basis of these results, it is planned to sample fish from different areas in order to determine if allele frequency differences exist at the variable loci, an indication that there is restricted gene flow among groups and subpopulations.

In late 1980, the Southwest Fisheries Center began an effort to improve its understanding of the North Pacific albacore population by integrating population dynamics, migration dynamics, known and hypothesized life history parameters, fishery information, economic information, and oceanographic parameters and processes into a formalized model. This model ("North Pacific albacore modeling progress report through August 1918" by N. Bartoo and L. Bledsoe) will permit the testing of hypotheses concerning the albacore population and its interaction with both the ocean environment and the harvesting fisheries.

The specific objective of the North Pacific albacore modeling project is to improve assessment of albacore stocks by 1) making a mathematical statement of current hypotheses on albacore stock dynamics (growth, mortality, recruitment, and migration as related to the environment) for comparison with observed data (fishery, tagging, etc.) as a test of the consistency of these hypotheses, and 2) developing alternative hypotheses to explain inconsistencies revealed by 1). Success in reaching these objectives will lead to improved management advice.

The North Pacific albacore modeling project is being developed in three general phases: 1) formulation of the model software and assembly of the support hardware, 2) compilation and formulation of the environmental data base to be used to quantify ocean processes affecting albacore as input to the model, and 3) estimation from fishery data of the needed model parameters (i.e., natural mortality, migration rates, etc.) for the initial hypothesis testing.

As of this writing, the initial formulation of the model is basically complete, although modifications are being made as research proceeds. Barometer estimates and functional relationships between variables are currently being estimated. The 1977 catch data are being used as the first trial data set and the behavior of the predicted catch and catch-per-effort is being evaluated with respect to changes in the values of the parameters. Work has also begun to correlate oceanographic and environmental indices to variations in catch-per-effort as inputs into the model.

The sixth paper submitted to the workshop dealt with the analysis of stock dynamics. N. Bartoo and K. Parker discussed a means of reducing or eliminating bias when estimating age structures from sampled length frequencies ("Stochastic age-frequency estimation using the von Bertalanffy growth equation"). The procedure uses a conventional von Bertalanffy growth equation but employs additional information on the probability of fish of a given length being assigned to a particular age. An example demonstrated the adequacy of the method. It was noted that this procedure could be used to age catches which contained strong and weak year classes.

Exploratory Albacore Longlining Operation Conducted in Mid-Winter 1982

The U.S. albacore fishery has traditionally operated during summer and fall months, usually within a few hundred miles of the North American coast. In some years it extends as far south as central Baja California, Mexico, and in some years as far north as northern British Columbia, Canada. In recent years, U.S. fishermen have also begun to fish for albacore eastward from near the international dateline during early spring and summer months.

In the spring of 1980, the American Fishermen's Research Foundation (AFRF) was awarded a Saltonstall-Kennedy grant, to be administered by the NMFS Southwest Regional Office in Terminal Island, California, to investigate the possibilities of expanding the U.S. albacore fishery to operate during winter months with longline fishing methods. The operational aspects of the study were carried on by AFRF and managed by the Western Fishboat Owner's Association (WFOA), a west coast association of albacore fishermen. Fishery scientists at the Southwest Fisheries Center (SWFC) planned the study and worked with the AFRF and WFOA to organize the study. In addition, the SWFC provided scientific equipment and fishery scientists who were aboard three of the chartered fishing vessels to make scientific observations and to keep detailed records related to the fishing operations and catch.

The objective of the study was to evaluate the potential for establishing a U.S. fishery on North Pacific albacore during winter months in eastern North Pacific waters. An area several hundred miles off the coast of southern California and extending to the longitudes of about the Hawaiian Islands was selected for the study. The purposes of the study were to: 1) conduct exploratory fishing using longline fishing methods in order to determine if sufficient catches of albacore can be made to suppport an expansion of the U.S. fishery, 2) make scientific observations to determine oceanographic conditions that may influence albacore distribution and catchability in the area, and 3) collect scientific data for albacore biology and fishery studies.

The study was actually carried out in two parts. During January-February 1981, the AFRF worked cooperatively with the SWFC to modify foreign and domestic longline fishing methods for albacore. The results

of this study showed that it was feasible for U.S. fishing vessels in the 50- to 80-foot size class to longline for albacore during the winter months. A limited quantity of gear was deployed with subsequent small catches in 1981; however, the catch rates were sufficiently high to suggest that a profitable winter albacore fishery could be developed.

The second study was designed to expand upon the 1981 findings. The amount of gear deployed was increased to reflect potential commercial efforts and a fishing strategy was proposed based upon the associations of catch and subsurface thermal structure found during the first survey.

Six chartered commercial fishing vessels conducted exploratory longlining operations for albacore tuna in an area centered about 1,000 to 1,500 miles west of San Diego during January-February 1982. A total of 70,939 pounds of albacore and 7,834 pounds of bigeye tuna was caught, with 7% of the albacore taken on trolling gear. The vessel landings ranged from 6,102 to 24,274 pounds of albacore and bigeye combined.

A total of 112 sets was made on the survey, with each vessel typically placing 800 to 1,400 hooks per set in and about the thermocline at depths of 350 to 700 feet. Daily longline catches ranged from 0 to 136 albacore. The mean catch per set for all vessels was 31 albacore, equivalent to 3.2 fish per 100 hooks (3.4 if bigeye tuna are included). The average hook rate varied among vessels: 1.6 to 4.8 per 100 hooks. There was some fish loss due to line twisting, part of which occurred as the gear broke the surface. This problem varied among vessels and can be largely reduced by modifications in gear and handling. The longline catches of albacore fell into two size groups, 14-18 pounds and 22-27 pounds.

The results of the 1982 study show that the U.S. albacore fishery can be extended to operate during winter months using longline fishing operations in an area where the fleet has not traditionally fished. This potential for a mid-winter albacore fishery exists as an important alternative for a vessel which now has the choice of participating in other winter fisheries or remaining idle. An additional factor of importance is that fuel consumption during the study was 40% to 50% below that typical for trolling operations.

U.S. Albacore Landings Up in 1981

U.S. albacore landings were considerably higher in 1981 than during the previous two seasons. Landings in 1981 were about 15,500 tons as compared to about 7,300 tons and 9,000 tons in 1979 and 1980, respectively. The seasonal 10-year average is about 20,000 tons.

The 1981 total includes fish caught by jig boats operating in the central Pacific in the "Midway" fishery and in eastern Pacific waters during the vessels' return to North America. It is estimated that these jig boats caught about 4,000 to 4,500 tons of albacore during the voyage. The landings made in 1981 are in part due to: 1) good fishing in waters

about 1,000 to 1,200 miles off the coasts of Oregon and Washington; 2) high catches of medium-sized, 12- to 16-pound fish off California, which is typical of a usual fishing season but which were under-represented in 1979 and 1980; and 3) late-season catches of large albacore off central California.

Albacore Movements Studied Using Acoustic Tracking

Ultrasonic acoustic tracking in conjunction with oceanographic sampling from ships and ocean temperature and color measurements made from satellites are being used by scientists at the SWFC's La Jolla Laboratory to investigate the distribution and small-scale movements of albacore tuna in relation to oceanographic features. Earlier work has shown that albacore aggregate in the vicinity of coastal upwelling fronts, presumably to feed, and that when the upwelling frontal boundary conditions break down as the result of shifts in wind conditions, the fish move away from the region where the boundary had existed.

Recent experiments using depth-telemetering acoustic tags have demonstrated that albacore spend most of the time in the thermocline and waters below, and relatively little time in the upper mixed layer as had previously been believed. The experiments, conducted in waters 1,200 miles off the coast of California, also show that albacore undergo marked vertical excursions in depth, with the extent and magnitude of vertical activity more pronounced in daytime hours than nighttime hours in nearshore waters and vice versa. Results indicate that the depth distribution of albacore is in deeper waters during daytime hours than in nighttime hours, with changes in depth distribution taking place at sunrise (deeper) and sunset (shoaler). The data indicate that albacore are often found in waters with temperatures (45-60° F) considerably colder than has generally been believed to be the optimal temperature preference for the species (60-68° F). It also appears that when undergoing vertical changes in depth, the fish frequently pass through a vertical gradient of temperature amounting to a 12 to 15° F change within a 20-minute period.

Acoustic tracking experiments were conducted during August 1982 in cooperation with the American Fishermen's Research Foundation from a vessel chartered by the west coast organization. These albacore were tracked for approximately 24 hours; one was tracked for about 15 hours. All the fish remained in the same parcel of warm water that was separated from waters to the north and inshore by a 4° F temperature gradient which the fish did not cross. As stated above, however, the fish passed through a vertical temperature gradient about three times greater than the horizontal gradient near the surface. These findings indicate that the causal factor(s) involved in the aggregation of tuna on the warm side of ocean temperature fronts is not related to thermal-physiological mechanism(s) as had been previously suspected. Instead, it appears that a behavioral mechanism(s) related to feeding may be responsible. Measurements of ocean color and water clarity made by the Coastal Zone Color Scanner on the NIMBUS-7 satellite in conjunction with the tracking study provide data which support this hypothesis.

Tetracycline-Marked Otoliths Studied in Age Determination Project

The daily ring increment method of ageing fishes assumes that there is a daily ring deposition on the otolith. An experiment is now being conducted by Robert Nishimoto and Dr. R. Michael Laurs at the La Jolla Laboratory to determine if this assumption is valid for albacore.

A total of 2,544 albacore was injected with tetracycline, tagged, and released during a 2-year period of field operations on albacore boats chartered by the American Fishermen's Research Foundation. As of this writing, there have been 178 recoveries of tetracycline-injected fish. In some cases, however, the otoliths or precise information on the fish's time-at-liberty were not available, so not all the recoveries are represented in the data used in the subsequent analysis.

Tetracycline "marks" were apparent on otoliths from 117 fish. Under ultraviolet illumination the appearance of the "marks" ranged from bright and clearly visible, to faint and sometimes difficult to see. However, in all of these cases, it was possible to locate the "mark" and to make ring counts.

The results from this experiment show that for tetracycline-injected albacore, the relationship between otolith ring increments and days-at-liberty is nearly 1:1 (see Figure 1). This finding demonstrates the basic assumption that the otolith daily ring increment ageing method is valid for albacore, at least over the size range of the fish that were injected, and that this method may be used successfully to age North Pacific albacore.

In addition, whole counts were made on otoliths from 47 albacore with fork lengths from about 30 to 50 cm, as part of a study to determine the length at first birthday. These fish were from the proposed southern substock of North Pacific albacore. Preliminary results show that the length at first birthday for an albacore from the southern substock is about 40 cm.

Daily ring counts made on otoliths from three fish with fork lengths between 30-35 cm from the porposed northern substock of North Pacific albacore indicate that the length at first birthday for fish from this substock is close to 35 cm.

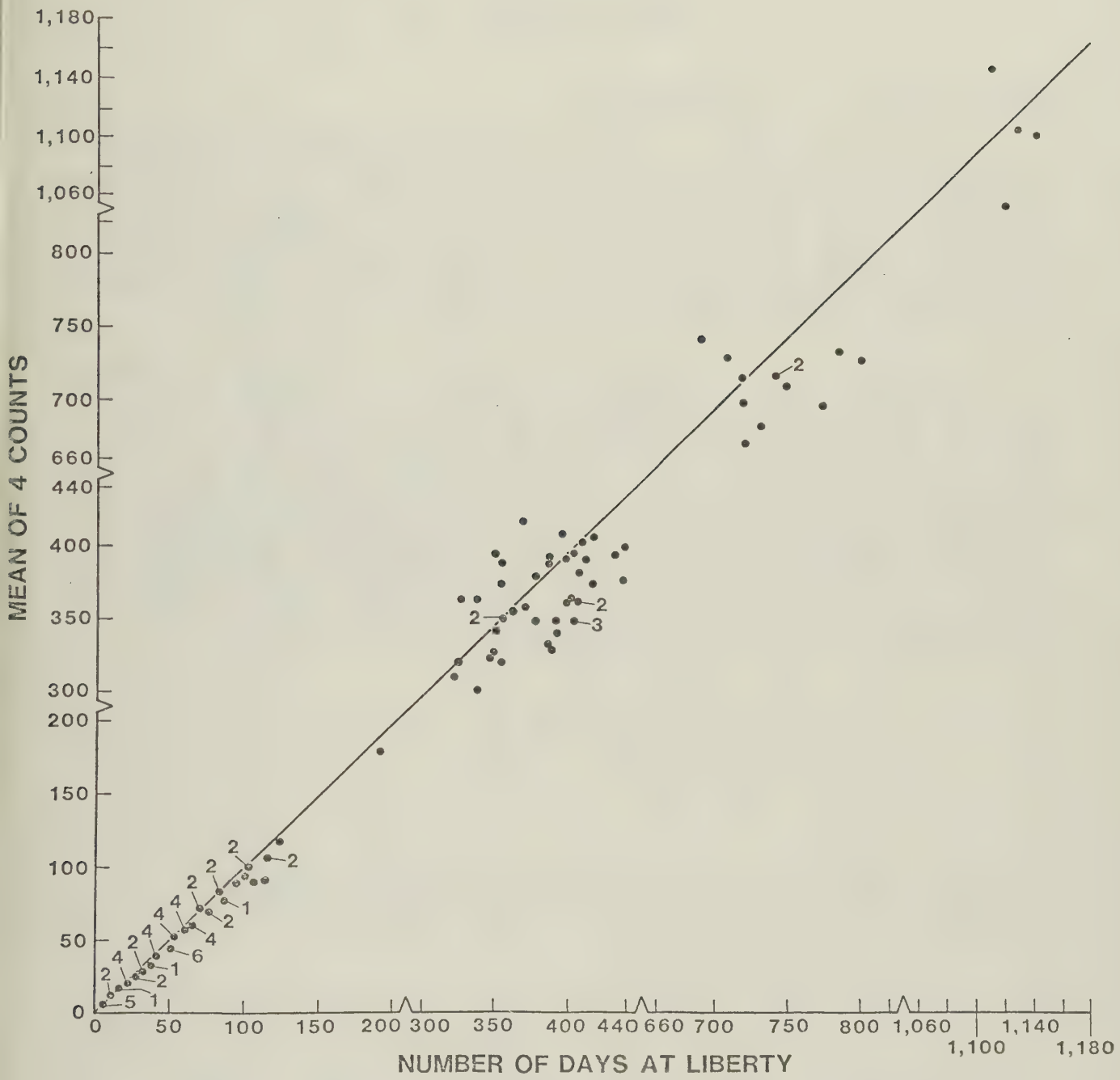

Figure 1. Relationship between otolith ring increments and days-at-liberty for recaptured albacore which had been injected with tetracycline prior to release on first capture.

NORTH PACIFIC BLUEFIN TUNA

Northern Bluefin Tuna Study Completed

California Department of Fish and Game marine biologist Doyle Hanan, stationed at the Southwest Fisheries Center in La Jolla, California, has completed a 2-year cooperative study on northern bluefin tuna. During the first year of the study, an extensive data base of existing information was established at the Center. The second year of the study was primarily concerned with analyzing these data. Hanan's report of the study, "A review of the northern bluefin tuna fishery in the eastern Pacific Ocean," will be submitted to a journal for consideration for publication.

Analysis of data collected for the study has revealed that the recent declines in total catch of northern bluefin tuna (10,561 mt in 1976 to 1,016 mt in 1981) have been accompanied by significant decreases in catch-per-unit-effort (Figure 1) by purse seiners operating in the eastern Pacific Ocean. The 1981 catch is the smallest commercial total since 1933 when bluefin tuna were fished almost exclusively by small purse seiners in California waters. Catch-per-unit-effort analysis has revealed declining abundance of northern bluefin in the eastern Pacific Ocean since 1954. An estimate of a 30% exploitation rate by purse seining in the eastern Pacific was made from the data on tag returns. Hanan recommends international discussion of the problems of the northern bluefin tuna.

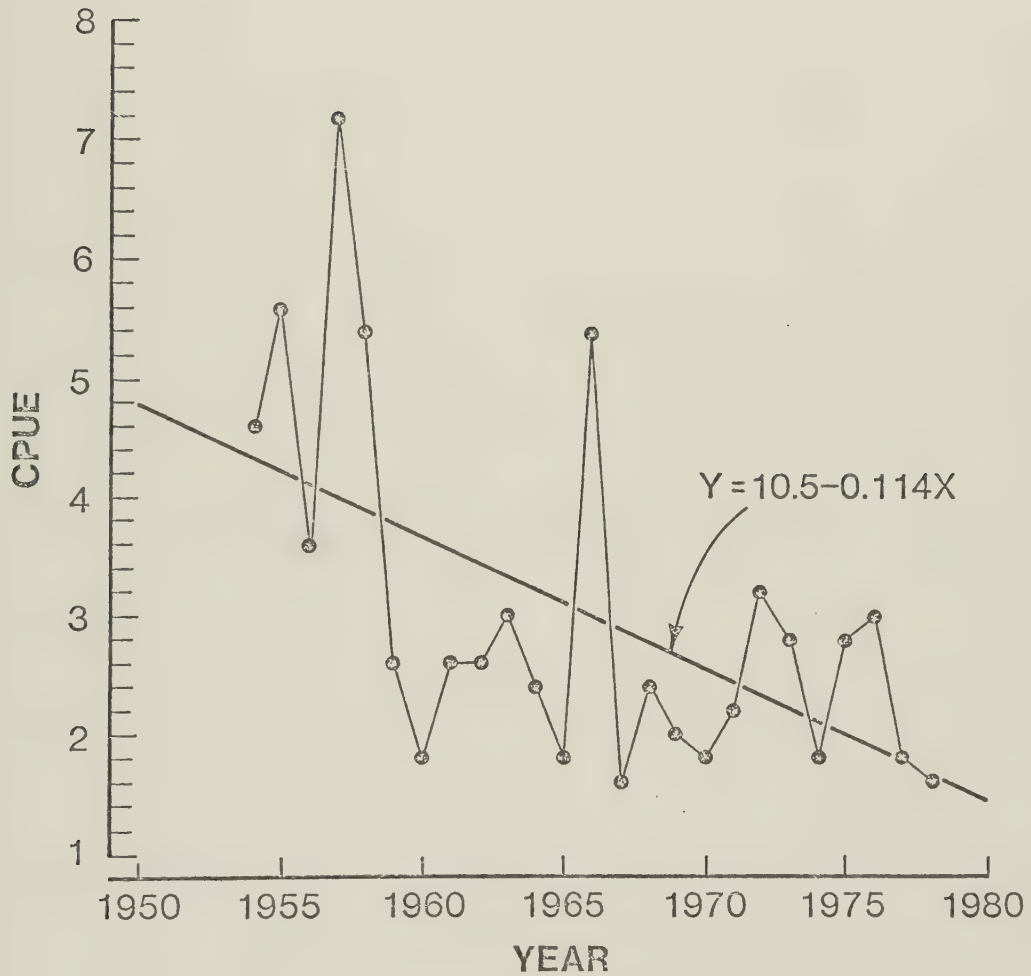

Figure 1. Catch-per-unit-effort (mt/boat days) of northern bluefin tuna in the eastern Pacific Ocean, plotted against year with regression line fitted to curve.

IN SUPPORT OF DOMESTIC REQUIREMENTS

PACIFIC FISHERY MANAGEMENT COUNCIL

Fishery Management Plan for Billfish and Oceanic Sharks Developed

The Pacific Council's Fishery Management Plan Development Team, with assistance from an advisory panel of commercial and recreational fishery representatives, prepared and published the second draft management plan for billfish and oceanic sharks in September 1981. Earlier in 1981, the Pacific Council approved the plan objectives for the FMP, and the FMP Development Team used these objectives in preparation of management options for the recreational fishery for striped marlin, the commercial harpoon fishery for swordfish, and the drift gill net fishery for swordfish and sharks.

The management team recognized in the draft plan that billfish and oceanic sharks are highly migratory species, and their fisheries cannot be effectively managed on a biological basis inside the limited area of the Fishery Conservation Zone (FCZ). Biological management of these stocks is an international problem, and management within the FCZ is approached from social and economic grounds. The objectives reflect the social and economic benefits that can be gained by exercising certain management options within the FCZ.

In October 1981, the Pacific Fishery Management Council decided not to continue with plan development. The recreational and commerical billfish harpoon fisheries conducted within the U.S. Pacific Coast FCZ continue to be managed by the State of California.

PACIFIC COOPERATIVE MARINE GAME FISH TAGGING

Since 1954, billfish have been tagged by fishermen participating in cooperative marine game fish tagging programs in many of the major sportfishing areas of the Pacific. The marine game fish tagging program is currently supported by the National Marine Fisheries Service in cooperation with the International Game Fish Association. James Squire, Fishery Biologist at the La Jolla Laboratory, coordinates the program. The tagging of sailfish by marine recreational anglers, formerly a part of the program, has been de-emphasized.

In 1981 some important changes were made in the tagging program. While striped marlin and swordfish will continue to be major targets for tagging efforts about the tip of Baja California, Mexico, and in southern California waters, three species of sharks which have recently been added to the list of desired species for tagging will also be targeted: thresher shark, mako or bonito shark, and blue shark. These three species of sharks are becoming increasingly important off southern California as market fish, and information on their migration patterns is needed. In addition to billfish, sharks (particularly mako) have been tagged in sizeable numbers about New Zealand

with the encouragement of the New Zealand Ministry of Agriculture and Fisheries.

Squire reports that 1,207 fish were reported tagged and released by participating fishermen in 1981. This is a substantial decline from the 1,725 fish tagged in 1980 but a significant increase over the 989 fish tagged and released in 1979. Of the 1981 total of 1,207 fish, 1,027 were billfish: striped marlin accounted for 836 (81.5%) fish tagged and released, sailfish for 114 (11.1%), black marlin for 48 (4.6%), and blue marlin for 27 (2.6%); one swordfish and shortbilled spearfish each were also tagged and released.

The number of tagged fish recovered in 1981 totaled 12, down from the 1980 recovery level of 24 fish. Nine striped marlin and three mako sharks were recovered.

The circumstances of angler recaptures of striped marlin tagged and recovered about the tip of Baja California, Mexico, in 1981 were unusual. In past years few marlin have been recaptured by anglers and most recoveries of tagged fish are from the commercial longline fishery. The commercial longline fishery in the eastern Pacific takes many times the amount of striped marlin landed by anglers. It was, therefore, expected that most of the recoveries would come from the longline fishery. However, nine striped marlin were reported recaptured by anglers and only one tagged fish was obtained from the commercial longline fleet.

Some very interesting information on returns has been gathered for mako sharks tagged and recaptured about New Zealand. Peter Saul, New Zealand Ministry of Agriculture and Fisheries, reported that one mako was recaptured 773 days after release, and only a short distance from the point of original tagging. These long-term recoveries are providing not only vital information on the rate of growth for mako sharks, but also data on migration patterns of these large game fishes.

PACIFIC INTERNATIONAL BILLFISH ANGLER SURVEY

The Pacific International Billfish Angler Survey has been conducted annually since 1969 in cooperation with the International Game Fish Association, and with the assistance of the Pacific Gamefish Foundation and marine angling clubs. The objective of the Survey is to determine the trend in billfish catch per angler day for various fishing locations throughout the Pacific. The information derived from this survey is summarized by geographical areas and species caught, and is available to anyone interested in billfish fishing trends. These data have been used by the federal government and state organizations in the development of management plans for billfish fisheries common to their areas.

This is the only international survey conducted to determine trends in angler billfish catch and effort. Historically, the commerical fisheries, such as the Japanese longline fishery, have maintained an excellent logbook record system and much of the catch-effort statistics available on the trends of commerical longline fishing for striped, blue and black marlin, and sailfish, and the determination of the general status of billfish stocks in the Pacific, have been derived from these data.

Information on the trends in catch-effort for the recreational fishery for billfish is important to the future management of billfish resources. The billfish angler catch-per-unit-effort (CPUE) estimates are given in terms of catch per angler day, as numbers of fish per day fishing, or as days of fishing per billfish caught. The catch rates may vary according to the variations in availability and catchability of billfish in the sportfishing areas and the abundance level of the stock that the fishery is operating upon. The catch rates are computed as an annual average, and billfish fishing catch rates in one area may be much higher at certain seasons of the year than indicated by the annual average.

According to James Squire, Fishery Biologist at the La Jolla Laboratory who compiles the Billfish Angler Survey reports, 5,905 billfish (striped, blue, and black marlin, Pacific sailfish, and shortbilled spearfish) were captured in 14,943 angler days in 1980. In 1979, a total of 12,343 angler days was reported, with 3,796 billfish caught. The 1980 survey response base was increased by 2,600 angler days and the number of billfish reported caught increased by 2,109 fish over 1979.

The 1980 reported billfish angler catch, by species and number of fish, was as follows: striped marlin - 3,351, Pacific sailfish - 1,130, black marlin - 677, and blue marlin - 663. Striped marlin constituted 57% of all billfish species reported. The Pacific-wide billfish catch rate for 1980 was 0.40 billfish per angler day, or 2.53 days per billfish. This was an improvement over the 1979 results when the catch rate was 0.31 fish/day or 3.25 days/fish. Squire noted that the Pacific International Billfish Survey recorded its highest overall catch rates from 1969-1972, with an average of 0.55 fish per day or 1.8 days per fish, well above the 1980 figures. Thus, while the commercial demand for striped, blue, and black marlin, swordfish, and sailfish continues to increase, the total Pacific catch of these species today is less than that observed before 1970.

Striped Marlin

The major catch area in the survey for striped marlin is about the tip of Baja California Sur, Mexico. The catch-per-unit-effort (CPUE) for striped marlin in this area has increased during the past three annual surveys (1978, 1979, 1980) from an average of about 0.3 to nearly 0.6 marlin per day. However, the 3-year average for 1978-1980 is still substantially below the average of about 0.75 marlin per day observed during the first 3 years of the

survey (1969-1971). The low point was 0.29 fish per day in 1977. In 1980, striped marlin catches about the tip of Baja California were excellent and this is reflected in the increased CPUE observed by the 1980 survey.

The CPUE in southern California continues to be about 0.1 marlin per day, a rate which has remained relatively stable throughout the survey years.

A positive correlation (r^2 = 0.81) has been made between the trend of catch per angler day of the recreational fleet (as determined by the Angler Survey) and the catch rate trend of the commercial longline fleet (in numbers of striped marlin per 1,000 hooks fished) cperating in the two 5°-latitude x longitude areas surrounding the tip of Baja California, Mexico. The longline CPUE for striped marlin caught by the Japanese fleet and the CPUE recorded for the recreational catch in the same general area off Baja California for the years 1969-1976 were analyzed to determine the correlation. The CPUE of the Japanese longline fleet was much higher in the early and mid-1960's (prior to the advent of the Billfish Angler Survey in 1969) and it is reasonable to assume, based upon the above correlation, that the recreational angler CPUE was also higher during this time period.

Black Marlin

The angler (recreational) CPUE for black marlin caught off the coast of northeastern Australia declined slightly in 1980 to 0.48 fish per day. The rate has remained relatively stable during the last three survey years (1978, 1979, 1980). The level of angler response for 1980 in the Australian area exceeded any previous year. A total of 602 black marlin was caught in 1,119 days reported in 1980.

Recent restrictions have been imposed by the Australian government on commercial longlining within the Australia's 200-mile zone. In years past both the recreational rod-and-reel and commercial longline fishery for black marlin operated in adjacent areas (much in the same manner as the striped marlin fishery off the tip of Baja California, Mexico). With the restrictions in force, the effects of this management regulation on the catch rate trend of angler CPUE for black marlin should be of interest to those concerned with the management of billfish resources.

Blue Marlin

The blue marlin angler CPUE for 1980 shows a slight decline from the previous 3 years. The data indicate that current CPUE rates are slightly higher than those observed during 1973-1976. Since blue marlin is recognized as a species that has been heavily fished, it is encouraging to note a relatively steady catch rate in recent years.

MARINE MAMMAL PROTECTION ACT OF 1972

Tuna/Porpoise Interactions in the Eastern Tropical Pacific Studied

In 1981, the staff of the Southwest Fisheries Center at La Jolla continued research on the population size and biology of dolphins involved in the tuna purse seine fishery of the eastern tropical Pacific as mandated in the MMPA Act of 1972. Three new approaches to improve stock assessment analysis were tested.

1) Precision aerial photographs, taken in an aerial survey in 1980, were analyzed by scientists from the Center and from the Inter-American Tropical Tuna Commission (IATTC) to obtain dolphin length measurements. Preliminary results suggest that the technique has sufficient precision for the data to be used in estimation of annual production of calves. The photographs can also serve for school size estimation. Comparison of counts of dolphins in the photographs with visual school size estimates suggests that visual estimates may slightly underestimate the school size for large schools.

2) The second approach involved the successful use of satellite-linked transmitters to track two dolphins off Hawaii. The experiment proved that a small telemetry system could be used for tracking dolphin movements with a satellite and showed that the technique would be useful in studying dolphin seasonal migrations, stock boundaries and school integrity.

3) Teeth from a large sample of offshore spotted dolphins killed in the fishery were examined for age determination using a new technique involving examination of the detailed structures in the teeth. Using information on the age composition of the kill, SWFC scientists can extrapolate information on the health of the dolphin stocks, such as their reproductive capacity within different age structures. This new technique for ageing dolphins was developed using teeth from captive Hawaiian spinner dolphins whose ages were known and whose tooth layers were marked from periodic dosages of tetracycline. The layers in the teeth were found to correspond to time periods.

A 2-month aerial survey experiment was conducted near Costa Rica to study the effects of environmental conditions on aerial sightings. The resulting data are used to estimate the density of dolphin schools. Repeated flights were conducted in the same area under different weather and sea states to determine if these conditions affect the ability of the aerial observer to see the schools.

Cetacean Reproduction Conference and Workshop Held

The Southwest Fisheries Center was one of the sponsors of an international conference and workshop entitled "Cetacean Reproduction: Estimating Parameters for Stock Assessment and Management," held November 28-

December 7, 1981 in La Jolla, California. Participants to the conference reviewed the behavior, functional morphology, and physiology of cetacean reproduction, and addressed problems and new approaches in methodology. The workshop covered collection, preparation, interpretation and use of biological data in stock assessment and management. The conference provided additional information for the continuing research program at the Center on the life history of small cetaceans.

IN SUPPORT OF OTHER DOMESTIC REQUIREMENTS

TUNA DATA MANAGEMENT

Documentation of Secondary Files Completed for Tuna Data Management System

Specifications have been developed for the expansion or enhancement of the Honolulu Laboratory's tuna data management system. Based on these specifications, the development and documentation of a series of secondary tuna catch and effort files with a common or standardized record format have been completed. This standardized format was developed earlier this year in a series of meetings and discussions between the Honolulu Laboratory's Data Management and Technical Services staff and tuna data users. It provides adequate control and identifying information to allow general purpose summarization of analytical software to be written and applied to all tuna catch and effort data without modification. In addition, use of the control and identifying information has been facilitated by a small library of subroutines and functions to simplify decoding, unit conversion, and labeling of output. This series of files, which presently encompasses only the more frequently used data, will be expanded to cover most of the tuna data after an initial trial and evaluation period.

Computer Simulation Model to Analyze Fish Population Dynamics and Harvest Policies

Dr. Jerry A. Wetherall, Leader of the Stock Assessment Study, and Marian Y. Y. Yong, Mathematician, are working on the final draft of their NMFS Technical Memorandum, "User's guide to SIMPOP, a computer simulation model for analysis of fish population dynamics and harvest policies," after reviewing comments on an earlier draft. The document describes a FORTRAN program which allows the user to study both transitional and equilibrium characterization of a self-generating population harvested by a single gear. Process models such as growth, natural mortality, catchability, effort, reproduction, and recruitment are all user-specified. Various tables and plot outputs display transitional and/or equilibrium results for selected model variables as well as summary statistics. The use of SIMPOP is illustrated with examples of applications to several fishery stocks including the North Pacific albacore.

HAWAIIAN TUNA FISHERIES

The pole-and-line fishery in Hawaii again had a poor season in 1981. The total 1981 statewide catch of skipjack tuna has been estimated to be 2,200 tons. Apparently, the State of Hawaii is having some difficulty in collecting catch and effort data from the fishing industry. The bulk of

the catch was made from a fishing fleet consisting of 13 full-time pole-and-line vessels. The industry has managed to survive economically by selling a substantial part of the catch through fresh fish market outlets and by taking advantage of the increased ex-vessel prices in recent years. The fishery continues to be plagued by baitfish problems. The Oceanic Institute received funds the past several years from State and Federal sources to culture mullet/milkfish for baitfish purposes. From all accounts the project appears to be a long way from nearing commercial production.

For the same reason indicated above, the landing figures for the Hawaiian longline fishery are not currently available.

The Hawaiian night handline fishery for tuna (commonly called ika-shibi fishery) currently represents one of the most impressive growth industries in Hawaii. From a handful of fishermen operating in the mid-1970's, the fishery currently has grown to include more than several hundred vessels. The ex-vessel value of the catch exceeds $5 million. The viabiity of the industry results from a growing export market demand (mainland, Japanese restaurants, and Japan) for sashimi-quality tuna and a continued local demand for sashimi. One of the problems faced by the industry is burnt tuna which has tended to have a negative impact on the industry.

TUNA BEHAVIOR AND PHYSIOLOGY STUDIES

Larval Skipjack Tuna Rearing Studies Continue

Dr. Andrew E. Dizon, Leader of the Pelagic Ecosystem Study at the Honolulu Laboratory, and his co-workers continued experiments to induce skipjack tuna to spawn using the "stress-induced" method and to rear larval skipjack tuna during the summer of 1981 at the Honolulu Laboratory's Kewalo Research Facility. Ova stripped from ovaries of fish caught on the Hawaiian bait boat F/V Corsair were fertilized (dry fertilization method) and placed in larval rearing tanks at a density of 20 per liter. All the eggs hatched within 32 hours after fertilization at 24.5° C and the larvae were feeding on rotifers, Brachionus plicatilus, by the third day after hatching. On the fourth day after hatching, the larvae were fed a harpacticoid copepod, Tigriopus sp., cultured at Kewalo. A major mortality of 50% occurred on the 5th day and on the 8th day only about 10 larvae were seen; on the 12th day the last two remaining larvae died. A check of the water quality in the rearing tanks indicated that the ammonia concentration was approaching levels of toxicity. In addition, larvae that died from the 8th to 12th day had stomachs that were either empty or had only a few rotifers, which indicated a possible dietary deficiency as a contributing cause in the mortality.

In order to determine whether the underlying cause of the poor success at rearing the larvae was due to water quality at Kewalo, batches of fertilized eggs from the next two trials were shipped to Dr. John R. Hunter, Fishery Biologist, at the SWFC La Jolla Laboratory. Results of the simultaneous rearing attempts at La Jolla and Kewalo were identical. The fertilized eggs hatched successfully but large larval mortalities occurred after 4 to 5 days.

To test further the larval fish culture systems and procedures at Kewalo, Dr. Richard W. Brill, the new leader of the Pelagic Ecosystem study (Dr. Dizon transferred to the La Jolla Laboratory in December) began experimenting with mahimahi, Coryphaena hippurus, which spawn spontaneously in captivity and are much easier to maintain in shoreside tanks. In March 1982, the mahimahi at Kewalo spawned repeatedly and the resulting fertilized eggs were divided among the Oceanic Institute, Waikiki Aquarium, and Kewalo. The mahimahi larvae being reared at Kewalo and the Waikiki Aquarium all died within 5 days after hatching. The Oceanic Institute was the most successful in keeping and rearing the larvae. The probable causes of mortality are being investigated and a new strategy for the next series of spawnings is being planned.

Study of Geomagnetic Orientation and Navigation in Pelagic Fish Proposed

Dr. Andrew Dizon, Fishery Biologist at the La Jolla Laboratory, Dr. Richard Brill, Fishery Biologist at the Honolulu Laboratory, and Dr. Joseph Kirschvink, California Institute of Technology, have submitted a joint proposal to the National Science Foundation to study "Geomagnetic orientation and navigation by pelagic fish." The proposal for the 2-year project was submitted through Caltech.

The study will explore the use in navigation of magnetic field cues by deep swimming aquatic animals. The magnetic field can provide not only compass directions, but time cues and local landmarks as well. The earth's magnetic field has been reliably shown to influence behavior and orientation in a wide variety of organisms, yet there have only been a handful of studies demonstrating successful conditioning to magnetic fields. Most conditioned responses have been difficult to obtain or have failed replication attempts. The work which has been done by Mike Walker (graduate student at the University of Hawaii), Dizon, and Kirschvink with yellowfin and skipjack tuna, and kawakawa at the Kewalo Basin Research Facility of the Southwest Fisheries Center in Honolulu is an exception. They have shown that the tropical tunas are easily conditioned to earth-strength fields and that these fish possess magnetite (a highly magnetic iron oxide material) in their ethmoid sinuses in sufficient quantities to serve as the basis for a magnetic sense.

Dizon, Brill, and Kirschvink are proposing to extend the studies into five general areas related to magnetoreception and its use for navigation

and migration in pelagic fishes. Using the conditioning experiments, they hope to discover which components tunas respond to in the geomagnetic field. An extensive survey of pelagic animals for the presence of magnetite (marlins, dolphins, and green turtles are also known to have it) is planned. If appropriate, the development and biological synthesis of this mineral will be examined (magnetite is absent in larval tunas, appearing at a later stage of development). Both scanning and transmission electron microscopy will be utilized to examine the fine structure of the magnetite crystals and their connection to the nervous system. Fishery data will be utilized to search for possible correlations between catch, distribution, and magnetic data. Finally, during the second year of the project, the investigators intend to track wild fish equipped with ultrasonic transmitters to examine movement patterns during natural and artificial magnetic storms.

Magnetite Presence in Blue Marlin and Yellowfin Tuna Examined

In December 1981, Michael M. Walker and Anjanette S. Perry, University of Hawaii graduate students conducting research in conjunction with the SWFC's Honolulu Laboratory, spent a week working with Dr. Joseph L. Kirschvink at the California Institute of Technology (Caltech) to carry out additional work on the presence of magnetite in marine organisms. Caltech has a more sensitive magnetometer than is available in Hawaii, which enabled Dr. Kirschvink, Walker, and Perry to test for the presence of magnetite in the head of blue marlin, and to do follow-up work done earlier at the Honolulu Laboratory's Kewalo Research Facility on the likely magnetic sense organ in yellowfin tuna and green turtle, Chelonia mydas. Work done earlier by Walker had confirmed that the magnetic material in the ethmoid bone complex of the skulls of yellowfin tuna was magnetite ($FeO.Fe_2O_3$).

Using the Caltech magnetometer, the researchers found magnetic material only within the ethmoid bones in the skulls of the five marlins tested. The ethmoid bone is also the site of magnetic concentration in yellowfin tuna. A large branch of the lateral line nerve in the blue marlin, which is presumed to be homologous to the suspected "magnetic nerve" in yellowfin tuna, occurs in close proximity to the ethmoid bone in the blue marlin. Dr. Kirschvink, Walker, and Perry speculate that they may be close to discovering the site of the magnetic sense organs in these species.

Results of experiments on the blue marlin magnetic tissues indicate that the small crystals found are probably magnetite and in sufficient quantity to serve as the basis for a magnetic sense organ. Electron microscope analysis of yellowfin tuna tissues which had been sacrificed fresh and then fixed, found two pieces of "hot" tissue which are likely to contain thousands, if not hundreds of thousands, of crystals. The researchers hope to determine whether and how those crystals are linked to the nervous system.

Walker and Perry presented papers on their work on tunas and green turtles, respectively, at the special session on "Biomineralization of magnetite by living organisms" of the American Geophysical Union held December 10, 1981, in San Francisco. Walker, with Dr. Kirschvink, also traveled to Washington, D.C. to attend the special session on "Biological generation and detection of magnetic fields" of the American Association for the Advancement of Science held on January 4, 1982, where Kirschvink presented a paper on their magnetite work. It was apparent from the papers presented at both meetings that the Honolulu Laboratory may well be the leader in this area of research, due in part to the opportunities available at the Laboratory's Kewalo Research Facility to work with experimental animals which are very amenable to magnetic sensitivity studies.

Olfaction Experiments Conducted with Yellowfin Tuna

Dr. Kim Holland, Hawaii Institute of Marine Biology, University of Hawaii, has been testing the reaction of yellowfin tuna to odors of opelu, squid, nehu, and other natural prey items at the Honolulu Laboratory's Kewalo Research Facility. Under rigorous control of experimental conditions, Dr. Holland has been able to demonstrate clearly a hierarchy of prey odor stimulatory effectiveness, and to show a definite response to natural prey odors in naive fish. Both of these results have never been clearly obtained before.

The eventual goal of this work is the use of odors to enhance the effectiveness of floating fish-aggregating devices and live-bait fishing methods for tunas.

Energetic Costs of Swimming Tunas Examined

Christofer Boggs, University of Wisconsin graduate student working at the Honolulu Laboratory, has been measuring swimming costs in tunas using changes in whole animal energy density, water content, and weight. These provide a direct measure of the total energy content of individual fish that have been starved or fed measured quantities for known periods of time. Reference groups of fish from the same school sacrificed at the time of capture were analyzed to provide equations for back-calculating the initial energy content of experimental fish.

Because the initial weight of growing fish cannot be back-calculated from final length, a technique was developed for making periodic measures of live weight. Over 50 tunas were weighed, many repeatedly, with only two subsequent mortalities attributable to the handling procedures. A procedure was developed that allows the use of a single standard sample of tissue as a predictor of whole fish energy density variables.

Energy losses of starved skipjack tuna swimming at measured speeds were found to match roughly the energy consumption predicted by theoretical power models and independent measures of respiration. The

skipjack swam at speeds between 1.3 and 2.1 body lengths per second, with a much higher energy expenditure than many other fish (notably salmonids) require for swimming at these speeds.

Analysis of the feeding experiments are incomplete but preliminary results indicate that growth of captive skipjack tuna was only one-half to one-third of that predicted by the above measures of swimming cost. This may be due to the artificial environment, stress, or the use of frozen smelt for food.

PUBLICATIONS

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Bartoo, Norman. 1981. Status report: North Atlantic albacore. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 87-97.

The North Atlantic albacore stock is fished by longline and surface gears. Surface catches (38,000 mt in 1979) have declined about 25% since 1960. Longline catches in 1979 were 11,000 mt. Available evidence indicates that MSY is about 60,000 mt, which is 10% to 15% above recent years' catches. Yield-per-recruit to the North Atlantic albacore fisheries is about 3.8 kg, with some increase possible with fishery changes. Recruitment indices indicate that spawning stock is low and recruitment highly variable. The fishery appears to be heavily exploited.

Bartoo, Norman. 1981. Status report: South Atlantic albacore. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 78-86.

Annual catches from the South Atlantic albacore stock have remained near 22,000 mt for the last few years. Current annual effort levels are near 100 million hooks, the level reached in 1972. Available evidence indicates that the stock is currently producing catches about 25% below estimated MSY and that a relatively high yield-per-recruit of about 7.7 kg is being realized. The South Atlantic albacore fishery supplies about 40% of the U.S. annual consumption through imports.

Coan, Atilio L., Jr. 1981. Status report: Atlantic yellowfin tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 9-33.

The status of Atlantic yellowfin tuna stocks remained unchanged from 1979 to 1980. Production model analyses indicate that the stocks are being fished at high levels, especially in the eastern Atlantic. Increase in fishing effort with the fishery operating within its present geographical boundaries is unlikely to produce substantial gains in yield.

In 1973, a minimum size regulation was adopted for Atlantic yellowfin tuna to decrease fishing mortality on small fish and to increase yield-per-recruit (YPR). Analyses indicate that a slight increase in

YPR has occurred for some fisheries since the adoption of the regulation. These gains may be less than predicted due to discarding of undersized fish.

Estimates of recruitment to the Atlantic yellowfin fishery have held relatively constant. Based upon these assessments, Atlantic yellowfin tuna stocks should be carefully monitored.

Coan, Atilio L., Jr., and Wesley Parks. 1981. Status report: Atlantic bigeye tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp.34-54.

Recent total annual Atlantic catches of bigeye tuna have averaged 41,000 mt. Major participants in the fishery include Japan, Korea, Spain and the USSR. The U.S. takes bigeye along with yellowfin and skipjack tuna in its eastern Atlantic tropical tuna purse seine fleet. Recent U.S. catches have been less than 500 mt.

The stock structure of bigeye tuna in the Atlantic is uncertain. Hypotheses include a single Atlantic-wide stock and separate north and south stocks. Catch-per-unit-effort shows slight decreasing trends.

Production model analysis estimates MSY in the range of 52,000-123,000 mt. Recent catches are below MSY. Recent estimated effort levels are 25 to 50% less than optimum effort. Analyses suggest that with current fishing patterns, increasing age-at-first-capture would slightly increase equilibrium yield-per-recruit.

The International Commission for the Conservation of Atlantic Tunas adopted a minimum size limit of 3.2 kg for bigeye tuna in 1979. The regulation, intended to increase yield-per-recruit, has not been in effect long enough for its effectiveness to be assessed.

Cramer, J.L., R.M. Nakamura, A.E. Dizon, and W.N. Ikehara. 1981. Burnt tuna: Conditions leading to rapid deterioration in the quality of raw tuna. Mar. Fish. Rev. 43(6): 12-16.

Burnt tuna is raw tuna which is paler and softer than normal. This study indicates that the burnt tuna condition results from muscle cell degeneration which begins prior to the death of the fish and proceeds more rapidly after death than in normal tuna. Female sex, longer fighting times, and less efficient chilling are positively correlated with the occurrence and severity of the burnt tuna condition.

Evans, R.H., D.R. McLain, and R.A. Bauer. 1981. Atlantic skipjack tuna: Influences of mean environmental conditions on their vulnerability to surface fishing gear. Mar. Fish. Rev. 43(6): 1-11.

Pertinent data and literature are examined to determine the effects of the environment on the spatial distribution of skipjack tuna, Katsuwonus pelamis, in both the Atlantic and Pacific Oceans. Environment/skipjack distribution relationships derived from this information are applied to long-term annual mean distributions of dissolved oxygen and thermal structure for the Atlantic Ocean between lat. 40°N and 40°S. The depth of skipjack habitat is mapped. Within the defined habitat areas, high vulnerability of skipjack tuna to surface gear is inferred and aerially compared with the long-term catch of the FIS (French, Ivory Coast, and Senegalese) fleet to confirm the validity of this approach. This technique is then used to hypothesize areas of vulnerability of skipjack to surface gear outside the range of the FIS fleet effort in the western Atlantic. Finally, the effects of surface winds on fishing operations are discussed and those areas where wind speed may hamper operations are outlined for the Atlantic Ocean between lat. 30°N and 30°S.

Evans, Richard H., and Norman Bartoo. 1981. Status report: Atlantic skipjack tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 55-77.

Eastern Atlantic skipjack tuna stocks are currently fished at a high level (100,000 mt in 1980) while western Atlantic stocks are fished at a low level (9,000 mt in 1980). CPUE indices for both the French-Ivory Coast-Senegal-Moroccan and Tema-based fleets, which are quite different and show no clear trend over time, are not considered to be adequate estimators of abundance. Available evidence indicates that neither western nor eastern Atlantic skipjack stocks are overfished at this time, and both stocks may effectively support increased fishing effort. This seems especially true for the western Atlantic, where a developing fishery off Brazil accounted for 80 percent of the western Atlantic catch in 1980.

Goldberg, Stephen R., and Hillary Herring-Dyal. 1981. Histological gonad analyses of late summer-early winter collections of bigeye tuna, Thunnus obesus, and yellowfin tuna, Thunnus albacares, from the northwest Atlantic and the Gulf of Mexico. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-14, 9 pp.

Gooding, Reginald M., William H. Neill, and Andrew E. Dizon. 1981. Respiration rates and low-oxygen tolerance limits in skipjack tuna, Katsuwonus pelamis. Fish. Bull., U.S. 79(1):31-48.

Oxygen-uptake rates and swimming speeds of voluntarily active skipjack tuna, Katsuwonus pelamis, at 23°-24°C were measured in the laboratory from captivity-habituated fish (0.6-3.8 kg) and at sea from just-caught fish (1.8-2.2 kg). In the shipboard tests, skipjack tuna swam 2-5 lengths/s (length = fork length) and consumed 0.9-2.5 (median = 1.3) mg O_2/g per h during their first 2.2 h of captivity. In laboratory tests, skipjack tuna swam at a mean speed of 1.4 lengths/s and consumed oxygen at a mean rate of 0.52 mg O_2/g per h.

For the laboratory fish, routine swimming speed (S,in lengths/second) was inversely related to fish weight (W, in grams)--$S = 3.12 - 0.53 \log_{10} W$; oxygen-uptake rate ($V_{O_2}$ in milligrams O_2/gram per hour) was directly related to both weight and speed (i.e., speed independent of weight effects)--$\log_{10} V_{O_2} = -1.20 + 0.19/\log_{10} W + 0.21 S$. However, laboratory fish swimming at their characteristic (weight dependent) speeds respired at rates independent of weight. Calculations based on the above interrelations among metabolic rate, swimming speed, and body weight indicated that skipjack tuna of all sizes may have an optimum swimming speed (for maximum distance per unit energy expenditure) near 2.1 lengths/s.

Captivity-habituated skipjack tuna (0.8-3.4 kg) also were subjected to a step decrease in concentration of dissolved oxygen (O_2) at 23°-24°C to determine their responses to acute hypoxia. At levels of O_2 below 4 mg/1, voluntary swimming speed increased as O_2 declined, reaching 3.9 lengths/s at the lowest test value of O_2, 1.4 mg/1. The 4-h median limit for log O_2 proved similar to the O_2 level critical for change in swimming speed, about 4 mg/1.

Experimental results are analyzed and compared with those from other fishes to arrive at the following conclusions: 1) The skipjack tuna's "standard" metabolic rate is two to five times that of typical fishes of similar size; 2) the weight exponent for "standard" metabolic rate of skipjack tuna is a positive value near 0.2, as opposed to the -0.2 value typical of fishes; 3) but, because the characteristic swimming speed of routinely active skipjack tuna is inversely related to weight, routine metabolic rate is virtually independent of fish weight; 4) highly active skipjack tuna can consume oxygen from air-saturated seawater at rates exceeding those known from any other fish of similar size; and 5) the skipjack tuna is relatively inefficient in its use of oxygen and food-energy for swimming (at least at low speeds) and it dies at O_2 levels still well above those lethal for other fishes.

Hanan, Doyle A. 1981. Status report: North Pacific bluefin tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 246-255.

Northern Pacific bluefin tuna are fished by surface gear including purse seine, trolling bait, gill net, trap, and harpoon in the eastern and western Pacific. Bluefin are also caught by longline in the western Pacific and, to a lesser extent, in the central and eastern Pacific and the east Indian Ocean.

The resource appears to be composed of a single stock; the western Pacific catch is composed of juveniles and mature adults while the eastern Pacific catch consists mainly of 1-, 2-, and 3-year old fish. Presence of a second stock off New Zealand is not confirmed by studies.

Herrick, Samuel F., Jr. 1981. Status report: Eastern tropical Pacific yellowfin tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 143-162.

The status of eastern Pacific yellowfin tuna has been evaluated using general production models and age-structured models. Results of the production model analyses indicate that the eastern Pacific yellowfin fishery is currently operating at levels above maximum sustainable yield. The age-structured analyses raise concerns over the increased dependency of the fishery on age-1 fish. Recent increases in age-1 catches could lead to a decrease in yield-per-recruit and a diminished potential yield. Heavy fishing on a succession of poor recruit classes could reduce the adult population such that recruitment failure occurs. Efforts to reverse these trends in the near future are complicated by a failure to reach agreement on a mechanism for implementing an eastern Pacific yellowfin conservation program in 1980.

Jennings, Jacqueline G., James M. Coe, and Walter F. Gandy. 1981. A corral system for examining pelagic dolphin schools. Mar. Fish. Rev. 43(11):16-20.

Kashin, S.M., R.W. Brill, W.N. Ikehara, and A.E. Dizon. 1981. Induced locomotion by midbrain stimulation in restrained skipjack tuna, Katsuwonus pelamis, L. J. Exp. Zool. 216:327-329.

The authors show that electrical stimulation of the midbrain of restrained and sedated skipjack tuna (Katsuwonus pelamis) produces coordinated locomotory activity. Their preparation therefore is a viable alternative for creating normal swimming movements which can be closely controlled by the experimentalist, and demonstrates that a midbrain "locomotory center" is present in skipjack tuna, as in other teleosts.

Kaya, Calvin M., Andrew E. Dizon, and Sharon D. Hendrix. 1981. Induced spawning of a tuna, Euthynnus affinis. Fish. Bull., U.S. (Note) 79(1):185-187.

Laurs, R. Michael, and Jerry A. Wetherall. 1981. Growth rates of North Pacific albacore, Thunnus alalunga, based on tag returns. Fish. Bull., U.S. 79(2):293-302.

Estimates of growth parameters for North Pacific albacore, Thunnus alalunga, were based on tag-recapture statistics, using the standard von Bertalanffy model and an extended model. Sequential estimation of L_∞ and K allowed us to test hypotheses concerning variation in growth rate between tagged albacore recaptured in different ocean regions.

Significantly lower growth rates were found in albacore recaptured off Japan and the United States north of latitude 40° north compared with those captured off the United States south of latitude 40° north. The differences in estimated growth rate were generally consistent with differences in length-frequency distribution of albacore taken off the United States north and south of latitude 38° north during the period when most recaptures were made. The findings add to a growing body of evidence that the North Pacific albacore population is not homogeneous; rather, at least two different subpopulations may exist.

Matsumoto, Walter M., Thomas K. Kazama, and Donald C. Aasted. 1981. Anchored fish aggregating devices in Hawaiian waters. Mar. Fish. Rev. 43(9):1-13.

Fish aggregating devices (FAD's) made of 55-gallon oil drums and wooden rafts were moored in Hawaiian waters off the islands of Oahu, Lanai, and Hawaii from May 1977 through July 1979. The FAD's successfully attracted numerous pelagic fishes, including large schools of skipjack and small yellowfin tunas. Commercial tuna pole-and-line boats benefited greatly by taking large catches of tunas from around the FAD's. Fishing around the FAD's resulted in reduced fuel and baitfish expenses. Trolling boats also benefited as they experienced a reduction in the number of zero-catch days. The success of the FAD experiment encouraged the State of Hawaii to implement its own FAD system involving 26 fish aggregating devices around seven major islands.

Mendelssohn, Roy. 1980. Using Box-Jenkins models to forecast fishery dynamics: identification, estimation, and checking. Fish. Bull., U.S. 78(4):887-896.

Box-Jenkins models are suggested as appropriate models for forecasting fishery dynamics. Unlike standard production models, these models are empirical, dynamic, stochastic models. Box-Jenkins models are not biased when estimating relationships between catch and effort, as are standard production models. The use of these techniques is illustrated on catch and effort data for the skipjack tuna fleet in Hawaii. An actual 12-month forecast is shown to give a reasonable fit to the observed data. Most of the discrepancies are explained by changes in the behavior of the fishermen (i.e., economic factors), rather than by lack of knowledge of the behavior of fish.

Riggs, Fletcher V. 1981. Status report: Tunas in the Indian Ocean. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 99-117.

The status of stocks of four species of tuna (albacore, bigeye, yellowfin, and skipjack) in the Indian Ocean was analyzed. Since 1962 estimated annual catch of albacore in the Indian Ocean has fluctuated widely between 10,000 and 28,000 mt. The estimated catch for 1978 was 14,600 mt. MSY lies between 15,000 and 20,000 mt. A

yield-per-recruit assessment suggests no gain in yield-per-recruit from harvesting the younger fish as fishing effort moved into more southerly waters. This stock appears fully harvested and there appears to be no reason for concern over the future of the stock at this time.

Estimated annual catch of bigeye tuna in the Indian Ocean reached a high of 48,000 mt in 1978. A production model analysis did not produce a reliable prediction of MSY. The yield curve showed increasing catch with effort and did not reach an asymptote. This stock appears to be only lightly exploited.

Yellowfin tuna in the Indian Ocean are fished by surface and longline gears. Estimated annual catch fluctuated widely from 1952 to 1978 but exhibited a general upward trend. The estimated total catch for 1978 was 62,500 mt. Production model analyses based on available longline fishery data suggest an MSY for that fishery of around 40,000 mt. Due to rather inaccurate total catch estimates, however, MSY may be higher. It is unlikely that longline catch could be increased appreciably above the current level. However, it is generally felt that there is a potential for increased landings of yellowfin tuna by surface fisheries.

The surface skipjack tuna fishery in the Indian Ocean is relatively undeveloped. Catches have fluctuated from 1965 on a generally rising trend. Estimated catch for 1978 was 32,600 mt. There have been no quantitative assessments of the Indian Ocean skipjack tuna stock.

Rinaldo, Ronald G. 1981. Status report: Eastern tropical Pacific skipjack tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 163-181.

The stock structure of skipjack tuna in the Pacific Ocean is poorly understood. In the eastern Pacific fishery for skipjack tuna, there appears to be no significant relationship between effort and apparent abundance. Yield-per-recruit analysis on a partial stock indicates a maximum yield-per-recruit could be obtained at a greater fishing effort than is currently applied. According to the IATTC, the fishery for skipjack tuna in the eastern Pacific does not appear to affect stock abundance, and there is no need to restrict the catch.

Squire, James L., Jr. 1981. Observations of albacore (Thunnus alalunga) fishing off California in relation to sea surface temperature isotherms as measured by an airborne infrared radiometer. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-11, 15 pp.

During airborne infrared sea surface temperature surveys, in cooperation with the U.S. Coast Guard and the U.S. Navy off the United States west coast, the location of albacore, Thunnus alalunga (Bonnaterre), fishing relative to sea surface temperature was

recorded. An association was found between albacore fishing and certain sea surface temperatures and discontinuities in temperature. Sea surface temperatures where albacore fishing was observed off southern California were 17.8° to 18.9°C (64.0° to 63.0°F) [sic]; and off central California were 15.6° to 17.2°C (60.0° to 63.0°F) and these temperature ranges are in general agreement with optimum fishing temperatures reported by other authors. On two occasions when the specific objective was to survey temperatures about the commercial albacore fleet, fishing was being conducted immediately west of a temperature discontinuity.

Further studies using the near-instantaneous airborne infrared sea surface and sub-surface survey techniques for temperature, in association with measurements of other physical and biological parameters, aided by satellite data, should be conducted. This would establish the true relation of isotherm patterns to the location and movement of the albacore fishing area for the ultimate development of reliable, tactical information for the fishing fleet and a better understanding of the factors determining the migration patterns of albacore.

Squire, James L., Jr. 1981. Status report: Pacific swordfish. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 256-276.

The stock structure of swordfish populations in the Pacific is not clear. Information and data evaluated at the Billfish Stock Assessment Workshop suggest that the population consists of either a single Pacific-wide stock, or northwestern, southwestern, and eastern Pacific stocks. Swordfish are caught by a variety of gear, but the majority are taken by longline gear designed for capturing tunas. For the 1952-1963 data series, a production model analysis gave a Pacific-wide MSY estimate of 20,000 mt with an effort level of 2.2 million hooks/5° area. The average (1966-1975) catch of 14,000 mt produced by 1.8 million hooks/5° area indicates that the fishery does not appear to be overexploiting the stock, and that the stock is in good condition.

Recent catches (1978) indicate levels of total catch equalling about 18,000 mt, approximately 2,000 mt less than MSY. High demands world-wide may drive the catch figure to the level of current MSY estimates or above within a short period of time.

Status reports on world tuna and billfish stocks. 1981. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, 300 pp + 2-page Appendix.

Stevens, E. Don, and Andrew E. Dizon. 1982. Energetics of locomotion in warm-bodied fish. Ann. Rev. Physiol. 44:121-131.

Stock assessment activities within the National Marine Fisheries Service. 1981. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-12, 130 pp + 34-page Appendix.

Uchiyama, James H., and Paul Struhsaker. 1981. Age and growth of skipjack tuna, Katsuwonus pelamis, and yellowfin tuna, Thunnus albacares, as indicated by daily growth increments of sagittae. Fish. Bull., U.S. 79(1):151-162.

Counts of the daily growth increments on otoliths provided the means for establishing growth curves for central Pacific skipjack tuna, Katsuwonus pelamis, up to 3 years old and for central Pacific yellowfin tuna, Thunnus albacares, up to 2 years old. The data indicated three stanzas of linear growth for 51 skipjack tuna ranging in size from 3 to 80 cm fork length. Estimated daily growth rates were 1.6 mm/day for fish up to a length of about 27.0 cm; 0.8 mm/day for fish between 27.0 and 71.4 cm; and 0.3 mm/day for fish between 71.4 and 80.3 cm. Growth data for eastern Pacific skipjack tuna ranging in size from 38 to 65 cm fork length suggested that skipjack tuna in the eastern Pacific grew at a slower rate than those from the central Pacific.

Age determinations of 14 central Pacific yellowfin tuna suggested two stanzas of linear growth. Estimated growth rates are 1.4 mm/day for fish up to a length of 64.2 cm and 0.9 mm/day for fish between 64.2 and 93.0 cm. Growth curves from this study were compared with published growth curves based on other methods.

The validity of daily growth increments was tentatively determined by observations on skipjack and yellowfin tunas held in captivity. Agreement of our growth curves with those of previous studies on the same stock of tunas using other growth estimating techniques also suggests that our ageing technique is acceptable. However, the day-to-growth increment relation and the effect of various variables on the formation of growth increments of tunas need to be investigated further.

Walker, M.M., and A.E. Dizon. 1981. Identification of magnetite in tuna. EOS; Trans., Am. Geophys. Union 62(45):850 [abstract only]. GPA4-2-5.

Highly migratory animals such as the tuna should find the ability to detect the geomagnetic field very useful in navigation. Recent discoveries of biogenic magnetite in a variety of species led us to search for magnetite in the yellowfin tuna, Thunnus albacares. We tested representative tissues and organs from seven juvenile yellowfin tuna for saturation induced magnetic remanence in the SQUID magnetometer at the University of Hawaii Institute of Geophysics. Tissue samples with signal to noise ratios greater than unity were weighed to calculate magnetic intensity and subjected to AF demagnetization.

High sIRM and magnetic intensity values were consistently obtained only for tissues from within the ethmoid bone complex of the skull of the yellowfin tuna. AF demagnetization experiments on frozen tissue samples from the ethmoid bone complex suggested that the sIRM of the tissue is carried by ferromagnetic crystals with coercivities between 9 and 10 milliTesla. An X-ray diffraction pattern obtained from the residue after hypochlorite digestion of the magnetic tissue identified magnetite as the source of the remanence. Behavioral studies have demonstrated magnetic sensitivity in yellowfin tuna. Magnetite contained in the ethmoid bone complex may be the basis for magnetoreception in these fish.

Weber, Earl. 1981. Status report: North Pacific albacore. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 228-245.

The North Pacific albacore stock is harvested primarily by the Japanese surface and longline, and North American surface fleets. Catches of these fleets have been in the vicinity of 100,000 mt in recent years, with a record catch of nearly 124,000 mt in 1976. The North American surface fishery, comprised primarily of U.S. troll vessels, landed an annual average catch of approximately 20,000 mt during the period of 1969 through 1978 but landed less than 5,000 mt in 1979. The U.S. imports an additional 80,000 to 90,000 mt of albacore to meet domestic demand and a substantial part of this originates from the North Pacific stock.

Although heavily harvested, the stock is considered healthy. Effort levels in recent years have been below those required to produce maximum average sustainable yields (MASY). Yield-per-recruit (Y/R) analyses indicated a decrease in Y/R following the expansion of the Japanese surface fishery. Slight gains in Y/R are possible through increased effort on larger fish but substantial gains are unlikely with the fishery in its present configuration. Catch rates for all three major fleets have shown gradual decreasing trends.

Weihs, Daniel. 1981. Effects of swimming path curvature on the energetics of fish motion. Fish. Bull., U.S. (Note) 79(1):171-176.

Wetherall, Jerry A. 1981. Status report: South Pacific albacore. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 212-227.

The South Pacific albacore stock has been fished since 1952. Most of the catch is taken by longline vessels from Japan, the Republic of Korea, and Taiwan. Longline catch-per-unit-effort declined considerably between 1962 and 1974 as effort and catch increased. However, catch rates increased in recent years so that average annual catch has increased recently in spite of lowered effort. Present average annual catch by longliners is in the neighborhood of the estimated MSY for this fishery, 35,000 mt, and no sustained increase

in longline catch can be expected. Potentials for expanding the surface catch of relatively small albacore are unknown.

Wetherall, Jerry A., and Marian Y.Y. Yong. 1981. Planning double-tagging experiments. NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-13, 44 pp (includes 3 Appendices).

Yoshida, Howard O. 1981. Status report: Billfishes in the Indian Ocean. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 118-141.

Billfishes are caught primarily as a by-catch on longline gear set to catch tunas in the Indian Ocean. Most of these billfishes appear to be sold in Japan where striped marlin brings the highest price, followed by swordfish, blue marlin, and black marlin. Tentative results from production model analyses indicate that no significant increase in total yield can be expected for blue and black marlin, whereas striped marlin yields could increase with increased effort. Swordfish and sailfish stocks do not appear to be adversely affected by current levels of fishing efforts. Additional statistics must be collected from the fleets of participating nations to give a clearer picture of stock status in these waters.

Yoshida, Howard O. 1981. Status report: Pacific striped, blue, and black marlins. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 277-300.

The blue marlin, striped marlin, and black marlin are primarily caught by longline gear in the Pacific. The available evidence suggests that blue marlin comprise a single equatorially-centered stock in the Pacific. Two hypotheses have been advanced for striped marlin stocks in the Pacific. The available evidence suggests the possibility of a multiple (two or three) stock structure for black marlin in the Pacific: one in the eastern Pacific and two in the western Pacific. The production model analysis, together with the declining catch rate, suggests that the Pacific blue marlin stock is being overfished. On a Pacific-wide basis, the striped marlin stock appears to be in good condition. No production model analysis is available for the Pacific black marlin. A high priority task is to better define the stock structure of marlins in the Pacific.

Yoshida, Howard O. 1981. Status report: Western Pacific skipjack tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 182-195.

The major fisheries for skipjack tuna are located adjacent to continents and islands. In the western Pacific, the Japanese pole-and-line, live-bait fishery is the largest and the oldest established fishery. The stock structure of skipjack tuna in the Pacific is not very well known. Although no production model analyses or other

analyses and simulations have been attempted for western Pacific skipjack tuna, all available information suggests that the resource is still underexploited. One of the important research needs for skipjack tuna in the Pacific is the elucidation of the population structure of the resource.

Yoshida, Howard O. 1981. Status report: Western Pacific yellowfin tuna. In: Status reports on world tuna and billfish stocks, NOAA Technical Memorandum, NMFS, NOAA-TM-NMFS-SWFC-15, pp. 196-211.

Yellowfin tuna are primarily caught by longline gear in the western Pacific. Although the stock structure of yellowfin tuna is not well known, it has been hypothesized that there are two separate stocks in the Pacific, one in the eastern Pacific and the other in the western Pacific, which are separated by a less clearly defined stock in the central Pacific. A stock production model based on longline catches of yellowfin tuna in the entire Pacific indicated that the stock is capable of sustaining the current level of catches.

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APPENDIX

MISCELLANEOUS INTELLIGENCE ON FISHERIES ACTIVITIES IN THE PACIFIC BASIN AND INDIAN OCEAN IN 1981

With a strategic location in the central Pacific, the researchers at the Honolulu Laboratory have unique qualifications and experience for gathering information on fishery activity, including tuna fisheries, in the Pacific Basin and Indian Ocean. Through wide personal contacts and correspondence, travels on official business, and participation and attendance at fisheries meetings and conferences, Richard S. Shomura, Director of the Honolulu Laboratory, and the staff of the Fishery Management Research Program maintain an active interest and involvement in the people and fisheries of this area.

Because of the need to keep abreast of rapidly moving events and to disseminate the information to interested persons, Mr. Shomura has prepared the following miscellaneous intelligence on fishery activity in 1981 throughout the central and western Pacific and the Indian Ocean:

Indo-Pacific Tuna Data Collecting Agency Created

As a result of an idea conceived at the Sixth Joint Meeting of the Indian Ocean Fishery Commission (IOFC) and the Indo-Pacific Fishery Commission (IPFC) Tuna Management Committees held in Perth, Australia, in February 1980, the FAO/United Nations Development Programme (UNDP) has started up a project to collect Indo-Pacific tuna data. As envisaged by the Committee, the objective of the project is to provide a mechanism for collecting tuna catch and effort statistics as well as other biological information for the Pacific and Indian Oceans.

Progress to date has been slow due to funding uncertainties and difficulty in locating a project leader; Arthur G. Woodland of the South China Sea Programme in Manila is presently acting as an interim supervisor until a project leader can be appointed. The project has been established in Colombo, Sri Lanka. A Japanese national, T. Sakurai, formerly Fishery Statistician at the Statistics and Information Department, Economic Affairs Bureau, Tokyo, has filled the tuna statistician's position for the project.

Results of South Pacific Commission Skipjack Programme Presented at Workshop

In August 1981, the South Pacific Commission (SPC) Tuna Tagging Programme held a workshop in Noumea, New Caledonia, to present preliminary results of the Skipjack Tagging Programme. About 153,000 skipjack tuna, Katsuwonus pelamis, were tagged during the 3-year field program. The release/recovery data have not been analyzed in detail but to date no major migratory patterns have been discerned. Examples of extensive

migratory movements of skipjack tuna were demonstrated by a fish tagged off Australia which was recovered in French Polynesia, a distance of more than 3,000 nmi from point of release to point of recapture. There are other similarly outstanding long-term movements.

At the August meeting, the program staff estimated that the stock size of skipjack tuna in the western Pacific may be as high as 10 million metric tons (mt). It should be noted, however, that more recent estimates of the standing stock are about 3 million mt.

During 1981 the SPC endorsed the development of a new tuna program which would include stock assessment of large tuna species (in addition to skipjack tuna) and the several species of billfishes of commercial importance. Dr. Robert E. Kearney is scheduled to head this new program. To date it appears that funds to operate this new program will be forthcoming from Australia, New Zealand, and the United States, at least for the first year.

Activities of Forum Fisheries Agency Monitored

The staff of the Honolulu Laboratory continued to monitor the activities of the Forum Fisheries Agency (FFA) in 1981. Reports are that a Mr. Coulter, from New Zealand, has been appointed the new Deputy Director of FFA. When the Director, William Razzell, left his post, Mr. James was appointed the acting director. It has now been learned that Mr. James, who formerly headed the fisheries department in the Government of the Solomon Islands, has taken a position with the Government of Kiribati.

There is an unconfirmed report that Alan B. Chapman, formerly Fisheries Advisor for the Maritime Authority of the Republic of Belau, has been appointed Fisheries Advisor for the FFA.

Reports Indicate Increased Tuna Fishing Activities in the Pacific and Indian Oceans

Purse Seining

In 1981 there was substantial purse seine fishing activity in the central and western Pacific by flag vessels of various nations. The U.S. fleet, consisting of about 25 vessels, and the Japanese fleet were very active. Fishing activities were successful on fish found in schools, near logs, and around fish-aggregating devices (FAD) or payaos. There also have been confirmed sightings of U.S.S.R. purse seiners in the western Pacific, and the U.S.S.R. has approached Indonesia for access to their 200-mile economic zone. Other nations showing some activity or interest in purse seining include Taiwan and Korea.

There appears to be a trend for many of the 25 U.S. purse seiners to operate year-round in the central and western Pacific rather than return

to the eastern Pacific for the yellowfin tuna, Thunnus albacares, season. Although the bulk of the central and western Pacific catch is offloaded at Pago Pago, American Samoa, some fish are being offloaded in Belau and Guam. Firm estimates of total catch are not available but a 40,000-ton figure has been mentioned as the U.S. catch in the central and western Pacific. The U.S. purse seine vessels appear to be equally adept at school fishing and log fishing and also attempt fishing around FADs. In December a U.S. purse seiner caught 500 tons of skipjack tuna in two successive days around a FAD located off Western Samoa. This is believed to have been an experiment conducted with the approval of the Fisheries Department of Western Samoa. The 1980-81 purse seine fishery for skipjack tuna in New Zealand was judged "poor."

The Japanese seiners appear to have achieved some expertise in purse seine fishing and plans are underway to increase the fleet. One report indicated that the Japanese purse seine fleet in 1980 numbered 14 vessels with projections for 18 vessels in 1982 and 40 vessels in 1983. Because of concerns in economic dislocation, Japan plans to increase purse seine fishing effort and reduce pole-and-line fishing capacity. Estimates of the Japanese purse seine catch in 1981 are not available but the 1979 catch totaled 31,000 tons. The Japanese purse seine effort is primarily focused on fishing around logs, although recent reports suggest some success in school fishing.

There is a purse seine joint venture currently operating in Fiji which has financial backing from New Zealand interests. The joint venture operates two New Zealand purse seiners, the Western Ranger and Western Pacific, which fish around a series of FADs anchored throughout Fiji waters. Catch data are not available and reports indicate the project has encountered problems with FADs breaking loose.

The purse seining activities in the Philippines and Indonesia also appear to be tied to joint ventures and the use of FADs. In the Philippines the joint ventures apparently are affiliated with Canadian and American interests and the purse seiners being used are old Canadian and American vessels. In Indonesia, the governmental enterprise, P.T. East Indonesian Fishery, which operates pole-and-line boats out of Waegeo, Maluku-West Irian, has a Japanese-built purse seiner which has been in operation since December 1979. The Japanese captain, who was inexperienced in tuna purse seining, fished initially in coastal waters off West Irian with poor results. Rumor has it that the boat is now fishing offshore on the same grounds fished by the Japanese, U.S.S.R., South Korean, and United States purse seiners, resulting in better catches. Confirmed details are lacking and there is no information available on its success to date. The Japanese tuna interests have an ongoing joint venture with Indonesia (it is uncertain whether the joint venture is with an Indonesian governmental corporation, the Directorate of Fishing Enterprises within the Directorate General of Fisheries, or with private industry). Although the details are sketchy, the operation involves Japanese-built purse seiners of the 300- to 400-ton class. The operation appears to be successful: catches of 150-200 tons are being made in 1-2 weeks.

In the Indian Ocean, there has been a recent report that the French Government is providing a purse seiner to carry out exploratory tuna fishing in waters off the Seychelle Islands. A previous attempt to carry out tuna pole-and-line fishing efforts in the Seychelles by the French was unsuccessful.

Pole-and-Line

Although purse seine fishing activities were increasing in the western and central Pacific, pole-and-line fishing activities were not at a standstill. With the exception of Japan, island nations in the Pacific as well as in the Indian Ocean are seeking means of developing their coastal pole-and-line fisheries. In addition to their own individual efforts, the means of developing fisheries include joint ventures with distant-water fishing nations.

There was a marked increase in placement of FADs in the tropical Pacific in 1981. Centers of activities include Hawaii, Western Samoa, American Samoa, Fiji, Papua New Guinea (PNG), Cook Islands, Indonesia, Guam, and the Commonwealth of the Northern Mariana Islands. The Maldives in the Indian Ocean have also installed FADs with FAO assistance. Undoubtedly, FADs have been placed in other areas. Activity in the payao fishery in the Philippines continues to be high.

Reports on pole-and-line fishing activity for the various established and developing nations in the Pacific Basin indicate that the fleet size and activity of the Japanese distant-water pole-and-line fleet appears to be on a decline. The peak of this fishery was probably in the late 1970's and early 1980's. The decline can probably be attributed to a number of factors, principally increased labor costs, substantial increase in fuel costs, and the establishment of 200-mile extended economic zones (EEZ) by many island governments.

The small (3,000- to 5,000-ton annual catch) pole-and-line tuna fishery based in Levuka, Fiji, continues to be viable and active. There have been recent moves to increase the fleet with newly built pole-and-line vessels. A U.S.-built vessel (Lepea), which has design characteristics of Japanese bait boats, is scheduled to fish around Fiji in 1982 and there is also talk of an additional pole-and-line boat being built for the fishery.

The Kiribati Government made a major move in 1981 to develop a pole-and-line fishery. A quasi-government/industry company managed by Richard James has been established. Currently, two pole-and-line vessels (gifts from Japan) are fishing for the company. Baitfish are being provided by the milkfish grow-out system developed under a project sponsored by FAO. Milkfish fry are caught in the wild and cultured in earthen ponds. Current plans are to transship tuna catch in containers to U.S. destination points; the first refrigerated container was transshipped to Hawaii via Majuro in late 1981.

The PNG pole-and-line fishing activities have been rather quiet in 1981. Negotiations for construction of a cannery by Star-Kist are continuing. A Japanese company operating out of a PNG base has pulled out for economic reasons; thus, Star-Kist appears to be the only foreign interest presently in PNC.

In New Caledonia a joint French-New Caledonia tuna fishing company began operations in 1981. In mid-1981, a 300-ton French-built pole-and-line vessel arrived in New Caledonia to fish under the Transpeche Nouvelle Caledonie joint venture. A second vessel was expected to join the operation in 1981. The vessels previously operated in the Seychelle tuna trials.

The Solomons pole-and-line fishery for skipjack tuna continues to be highly successful. The fishery is a joint venture between the Taiyo Fishing Company of Japan and the Government of Solomons. Current plans are to build a new cannery in the Solomons to replace an older one presently in operation.

Indonesia continues to attract attention as a site for substantial tuna fisheries development. In addition to the joint venture with the Japanese (purse seine FAD operation), there are a number of small pole-and-line fishing operations, most of them located on the eastern part of the Indonesia Archipelago. The total number of boats is estimated at 500 vessels, nearly all small (around 30 gross tons). In 1981, outside interests made a number of visits to review the tuna fishing activities in Indonesia. The available information on catch shows an estimated 102,000 mt of tuna caught in 1978, of which 33,000 mt were reported to be skipjack tuna.

Van Camp is continuing its freezer operation in Belau. Currently a fleet of about 12 pole-and-line boats fish for Van Camp, several of which are owned by Palauan nationals. Because of the soft worldwide tuna market, there are reports that fishing has come to a virtual stop. Star-Kist currently operates a carrier ship out of Belau. There apparently are two joint ventures operating in Belau. One is a katsuobushi operation, a joint venture with Japanese interests. The skipjack tuna catch is provided by two Japanese purse seiners (approximately 200-ton class). The operation is active and the excess catch has been sold to Van Camp. A second joint venture, a purse seine-FAD operation, involves Philippine interests. Reports are that the joint venture has installed approximately 20 FADs in the waters around Belau but there is no information on its success to date.

The Maldives pole-and-line fishery continues to be the most productive tuna fishery in the Indian Ocean. Several studies have been undertaken in recent years by fishing interests and financial institutions. Japanese interests currently appear to have a foothold in the area and have aided the Maldivian Government by transforming the fishery from a sail-driven to a motor-powered operation. In recent years, the Japanese have purchased the skipjack tuna for transshipment to Japan

via reefer-ship operation. The Maldivian fishery is reported to land approximately 40,000 mt of skipjack tuna.

In the 1960's, with the aid of French support, a small pole-and-line fishery was developed in the northern part of Madagascar. For political reasons, the fishery ceased to operate when the French were asked to leave in the 1970's. There are rumors that the Government of Madagascar is planning to reestablish a pole-and-line fishery for skipjack tuna aided by Japanese tuna companies.

Longlining

The tuna longline fisheries continued to operate in spite of all the attention on the development of purse seine and pole-and-line fisheries.

The Japanese longline fishery has been plagued with access problems. In 1981, the Government of Australia put longline fishing off limits in the black marlin (Makaira nigricans) fishing grounds off Cairns. In addition, restrictions have been imposed by Australia and New Zealand on the Japanese longline fishery for southern bluefin tuna (Thunnus thynnus), as part of an initiative to promote development of their own domestic fisheries. Indonesia closed its fishing zone, including the important bigeye tuna (Thunnus obesus) grounds in the Banda Sea, to Japanese longliners.

The foreign flag fleet longline fishery based at American Samoa in 1980 consisted of 106 vessels from Taiwan and 175 from South Korea. The 1980 tuna and billfish catch landed in American Samoa was estimated to be 32,600 mt, including 9,700 mt of yellowfin tuna, 18,100 mt of albacore (Thunnus alalunga), 3,600 mt of bigeye tuna, 1,000 mt of marlin, and 200 mt of wahoo (Acanthocybium solandri).

From all accounts, the small longline fishery (estimated to be about 18-20, 100-gross ton boats) based on Sabang (Sumatra) and Bali, Indonesia, continues to operate. Each field base has a 900-mt cold storage facility that can process 5 mt per day. Details of this fishery are not currently available.

Tonga's longline fishery (one or two vessels) continues to operate. In the Indian Ocean, one of the two 100-gross ton longline vessels in Sri Lanka apparently is still operating. The government is seeking outside funding (UNDP) to expand the longline fleet.

In other tuna fishery developments, the handline fishery for large tunas (similar to the Hawaiian handline fishery) currently operates in conjunction with the Philippines FAD fishery. It is reported that the catch from the small handline fishing boats (bancos) are being purchased in the field by Japanese and other interests. The catch is air-shipped to Japan and other areas. Apparently burnt tuna are also a problem in the Philippine fishery; the unavailability of ice and lack of any insulation add to the problem.